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# ***Nuts & Volts***

September 2005

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### **The Family Tree**

**Build a Pool Timer**

**Generating Analog Waves  
From Digital Signals**

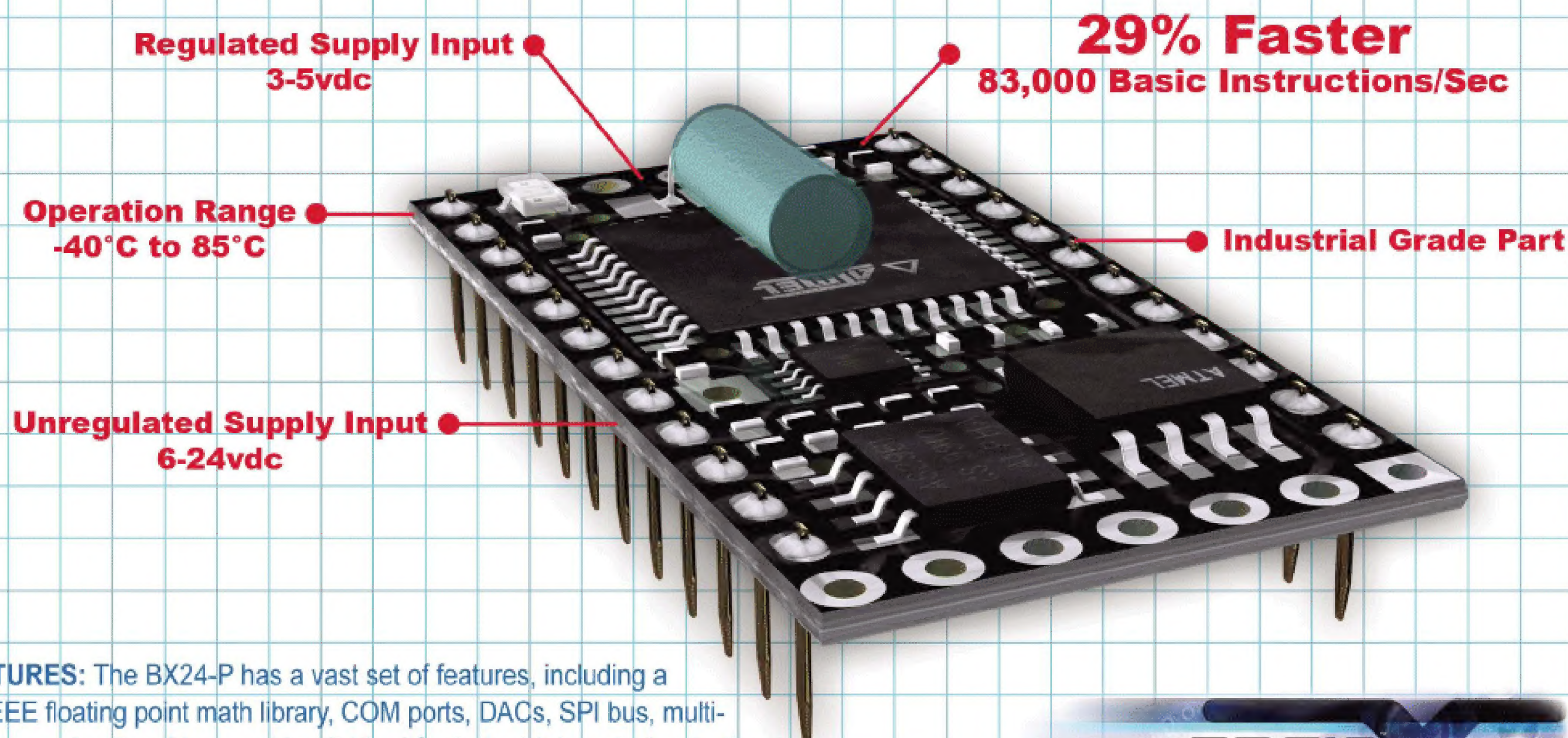
**The Space Elevator**



# Announcing the BasicX - BX24-P

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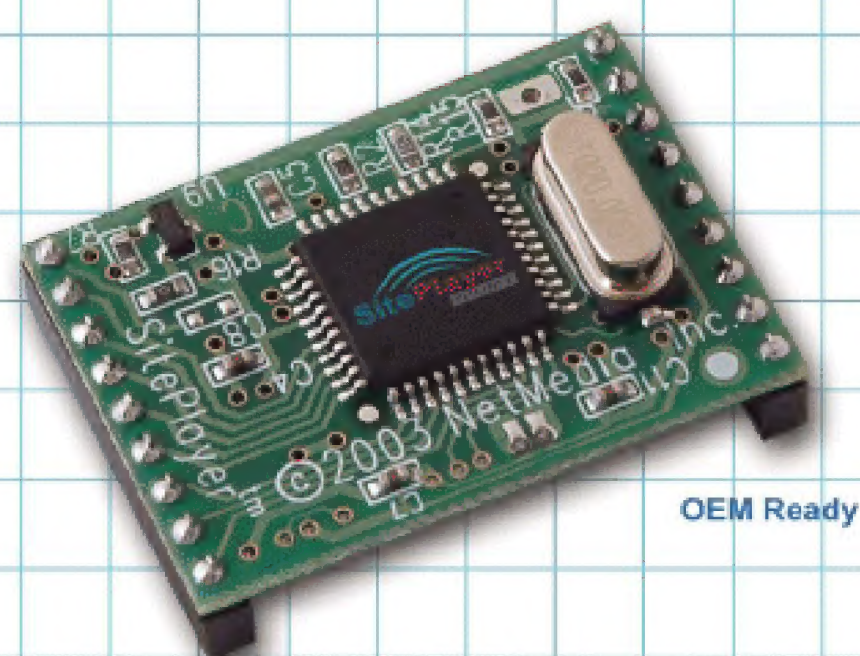
## Announcing SitePlayer Telnet™ Serial to Ethernet Data Converter

Enable your serial devices to communicate across Ethernet

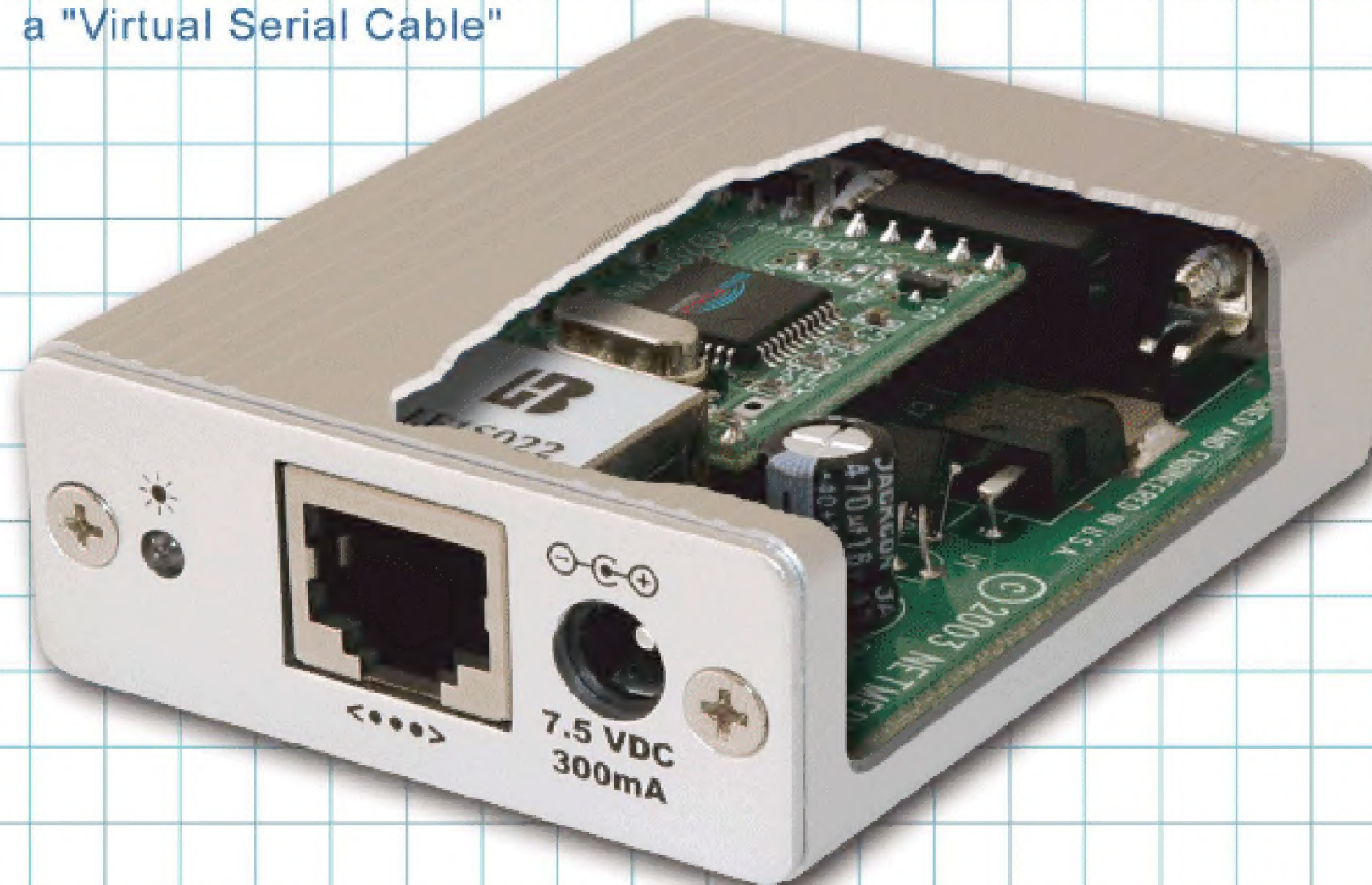
The SitePlayer Telnet module gives OEM's and product designers the ability to quickly and cost-effectively bring their products to market

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NetMedia Inc., 10940 N Stallard Pl, Tucson Arizona 85737 tel.520.544.4567x101 fax.520.544.0800 [www.siteplayer.com](http://www.siteplayer.com)



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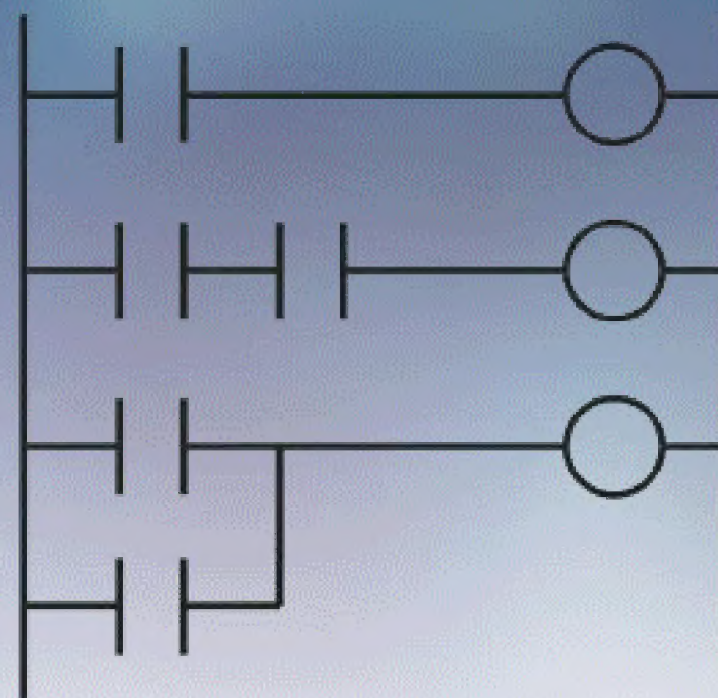
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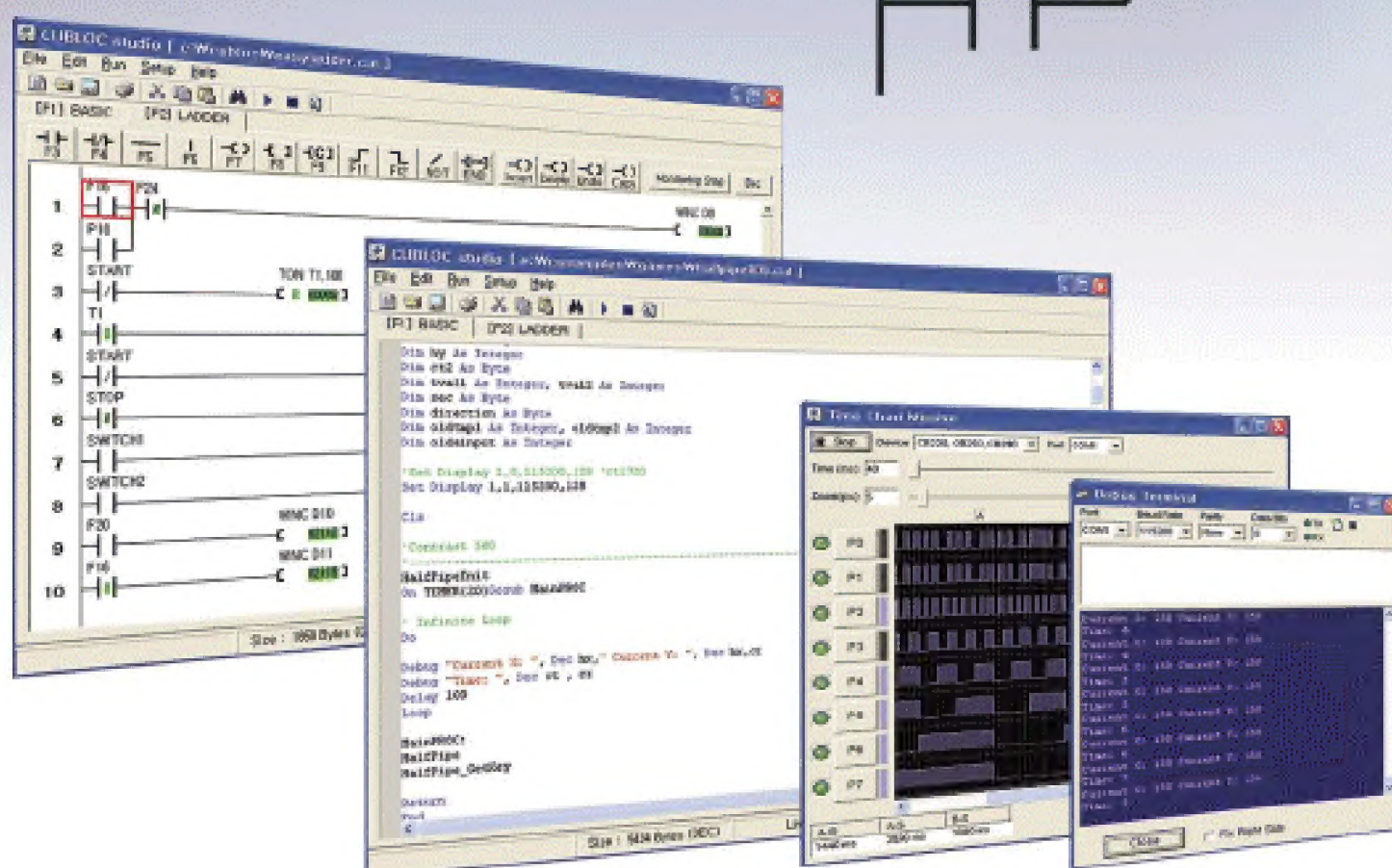


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# Nuts & Volts

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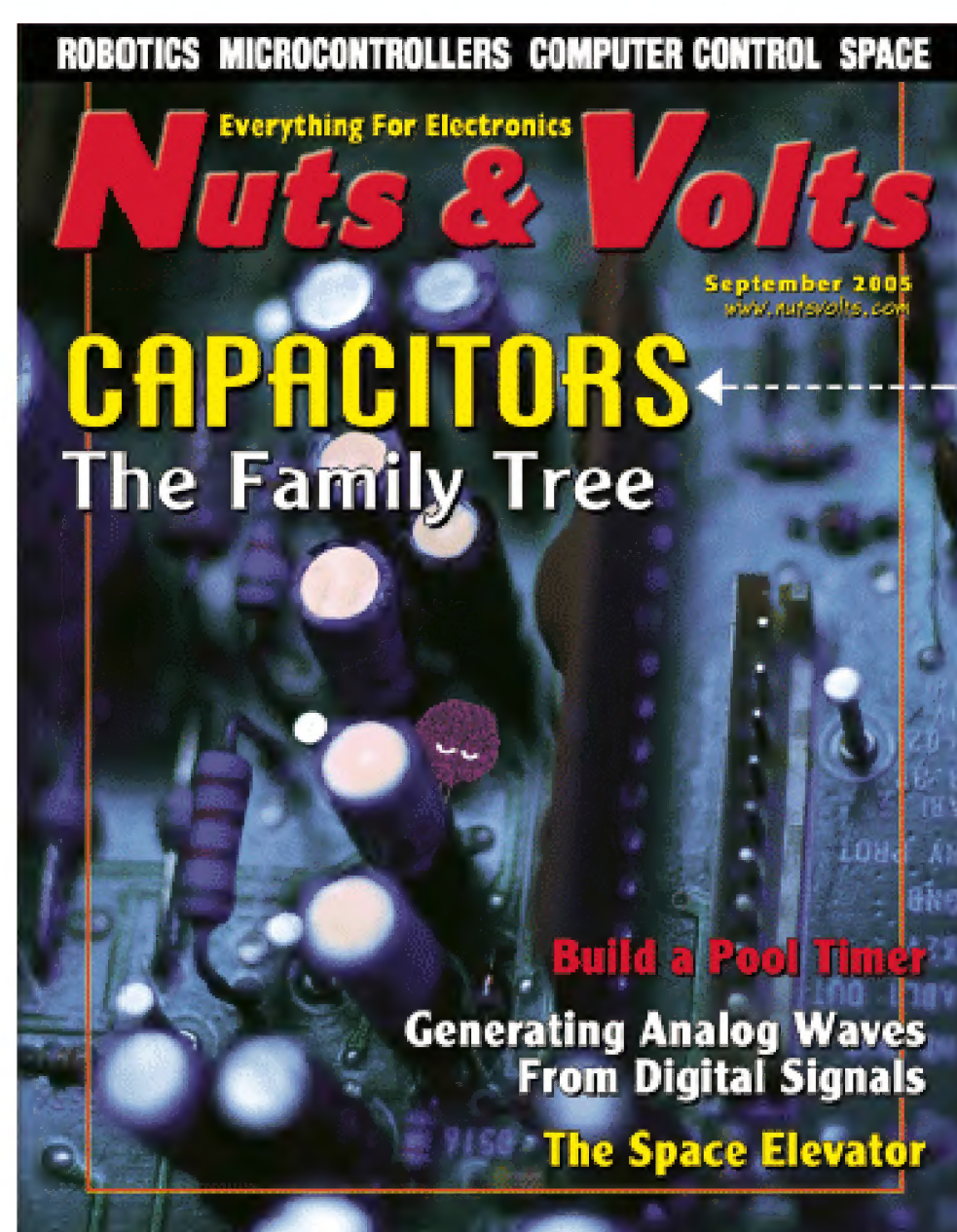
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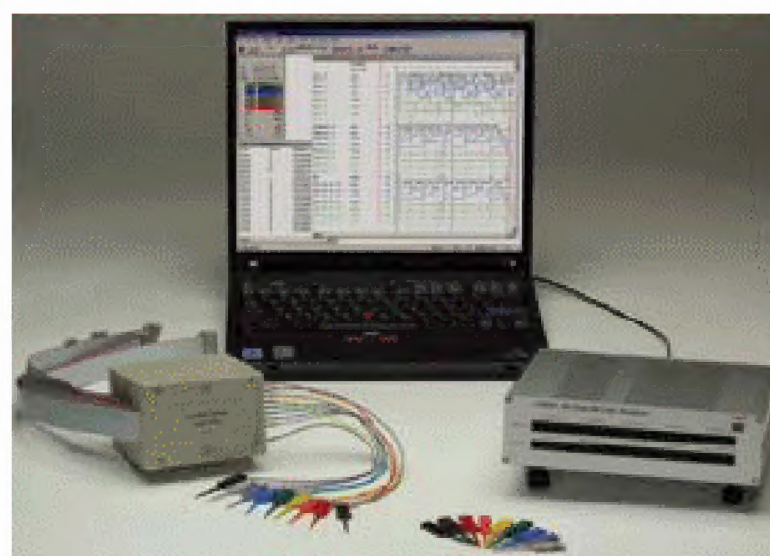
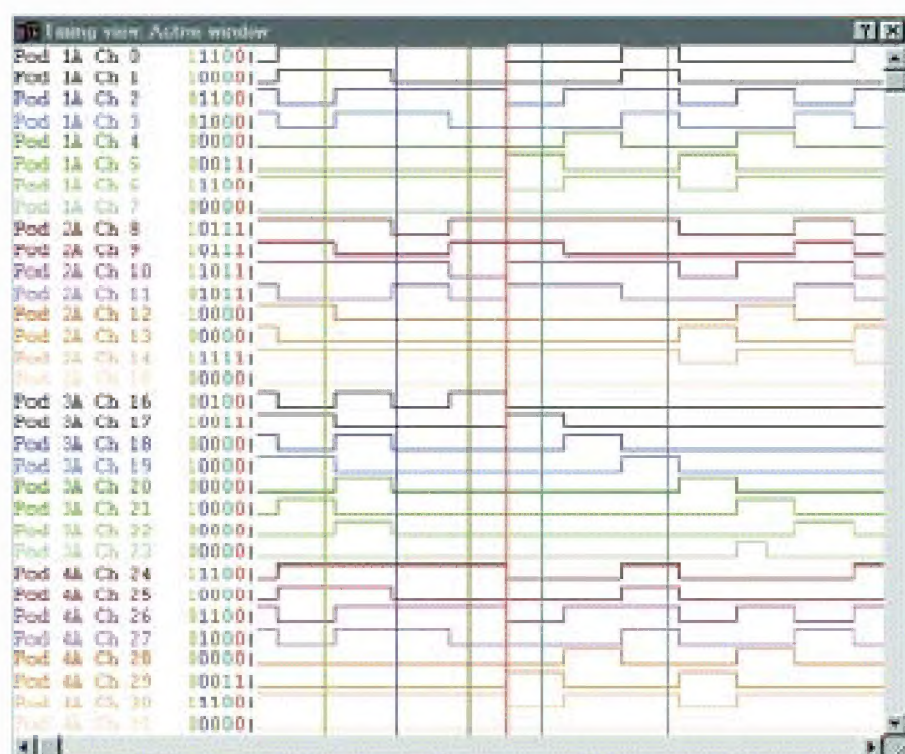


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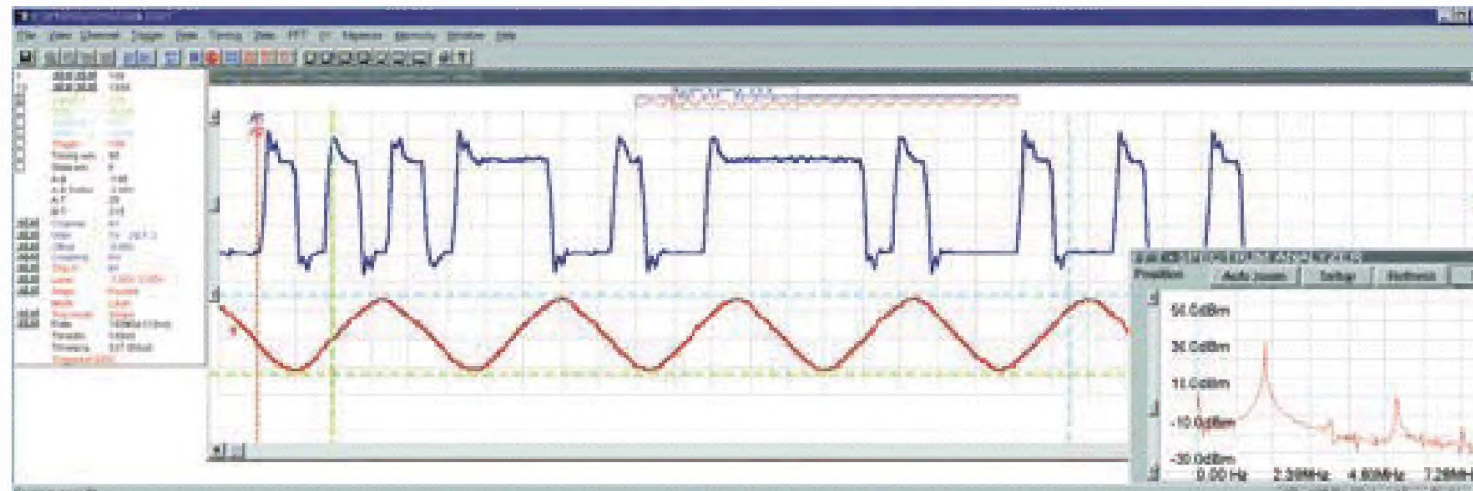
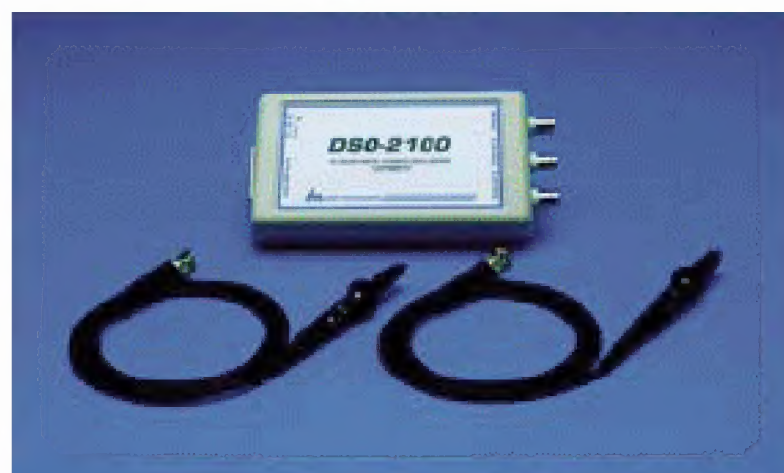
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# Reader Feedback

Dear Nuts & Volts:

In the August issue, page 15: 0.05 and 1.0 mA at 400 volts comes out to a resistance of 8,000,000 and 400,000 ohms using my Ohm's Law. Does anyone proofread this copy?

**Thomas Ely  
Bloomfield, NY**

*Actually, we do. What happened was TJ used the mu symbol in Word 6 for uA and the font we use changed the character into an "m" in the translation. Our apologies for the "oops."*

— NV

Dear Nuts & Volts:

Edward Driscoll, in his "Micro Memories" article in the July issue, shows great knowledge of the Computer History Museum and no insight to the history of Moffett Field, CA. He states the large hangers there were built to house Navy blimps, but, although they sometimes did house blimps in the WW2 era, they were built to house rigid airships — an entirely different machine.

The main hanger (pictured in the article) housed the USS Macon (ZRS-5) from October 1933 until her loss in February 1935. The Macon was 785 ft. long with a complement of about 100 personnel. She had eight 560 HP Maybach engines giving a speed of about 85 mph. Moreover, she carried

five F9C fighter aircraft, which she could launch and retrieve in flight. Hardly a "blimp."

**E. A. Grens**

Dear Nuts & Volts:

I really enjoyed the article on Managing Engineers in the July issue! In fact, I'd like to give a copy to my supervisor. Then he'd have an idea on how I like to be treated. Thanks for a great magazine!

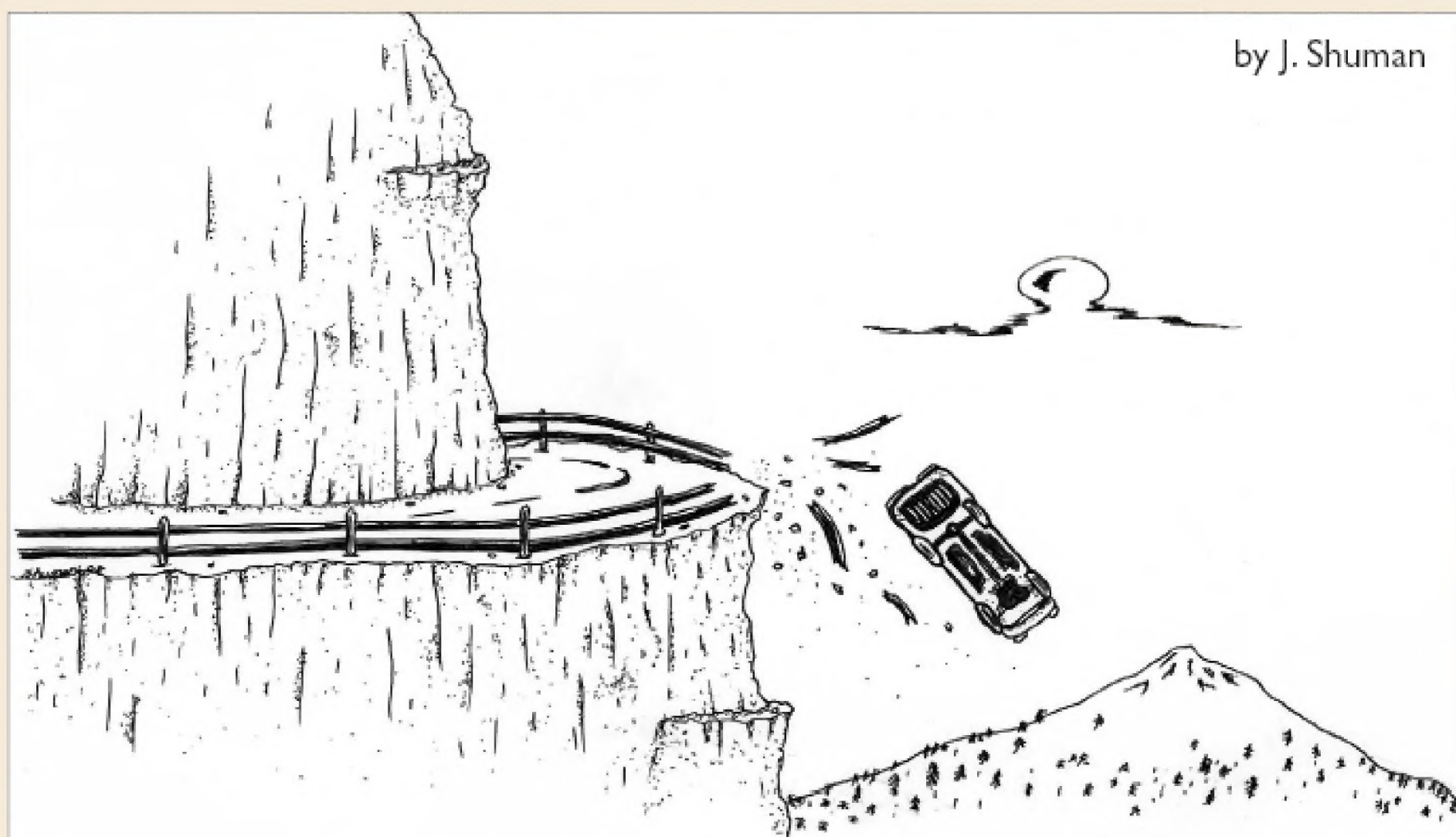
**Matthew Turnbaugh  
United Kingdom**

Dear Nuts & Volts:

I've been following your Near Space columns with considerable interest, even though I don't foresee actually engaging in the activity (there's a limit to how much one person can do, after all!). But your recent column (in the July 2005 issue) generated some thoughts in my mind that, even though not a particularly pleasant topic, I thought I needed to share with you.

When you mentioned the possibility of a balloon, or a payload, coming down on some farmer's field, it generated the thought "what if it comes down on the farmer?" This is my way of pointing out that one topic that I don't believe you've ever mentioned, but unfortunately needs to be discussed in today's litigious society, is the issue of potential liability

by J. Shuman



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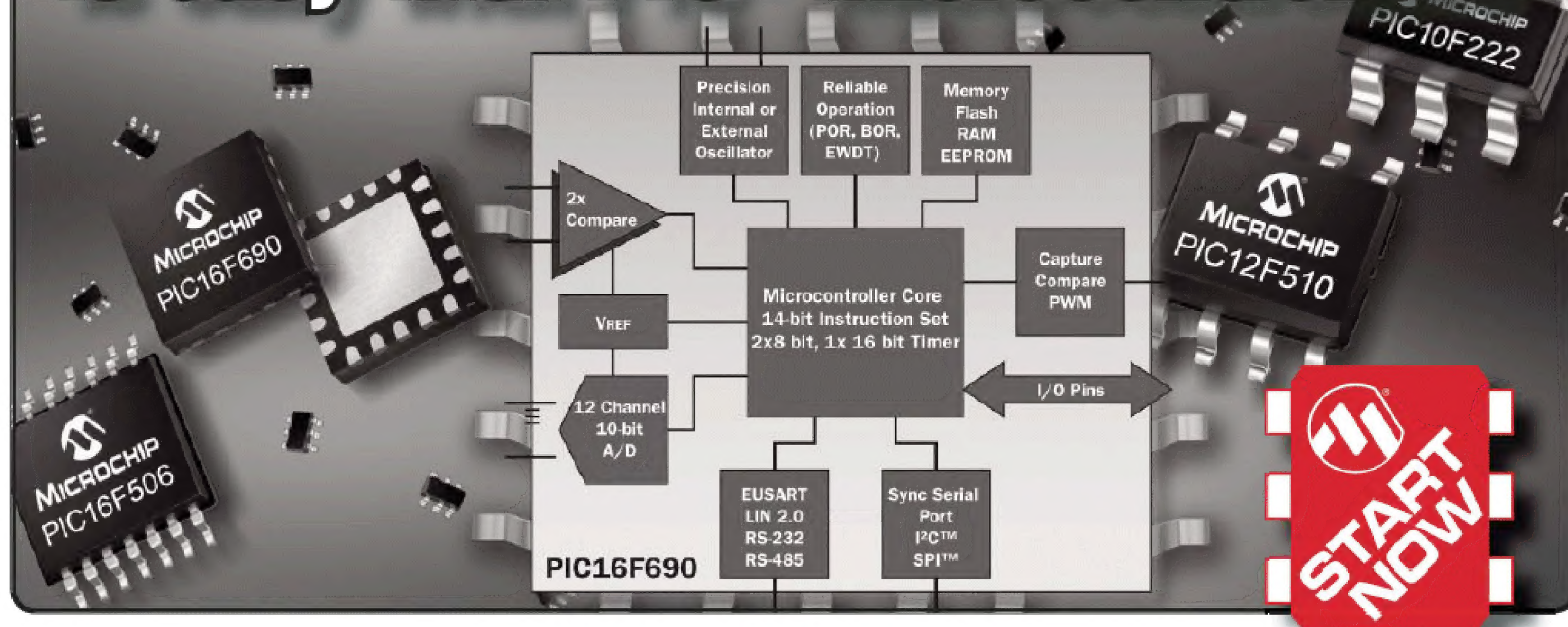
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Peripheral-Rich Mid-Range PIC Microcontroller	PIC12F	14-bit	8	1792 to 2048	32 kHz to 8 MHz	10-bit	●	●	●	●
	PIC16F	14-bit	14 to 64	1792 to 14336	32 kHz to 8 MHz	10-bit	●	●	●	●

\* Easily migratable to Mid-Range PIC Microcontroller Architecture; † Microchip's proprietary low power technology.

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# TechKnowledgey 2005

Events, Advances, and News  
From the Electronics World

## Advanced Technologies Get Your Fingers Off of Me

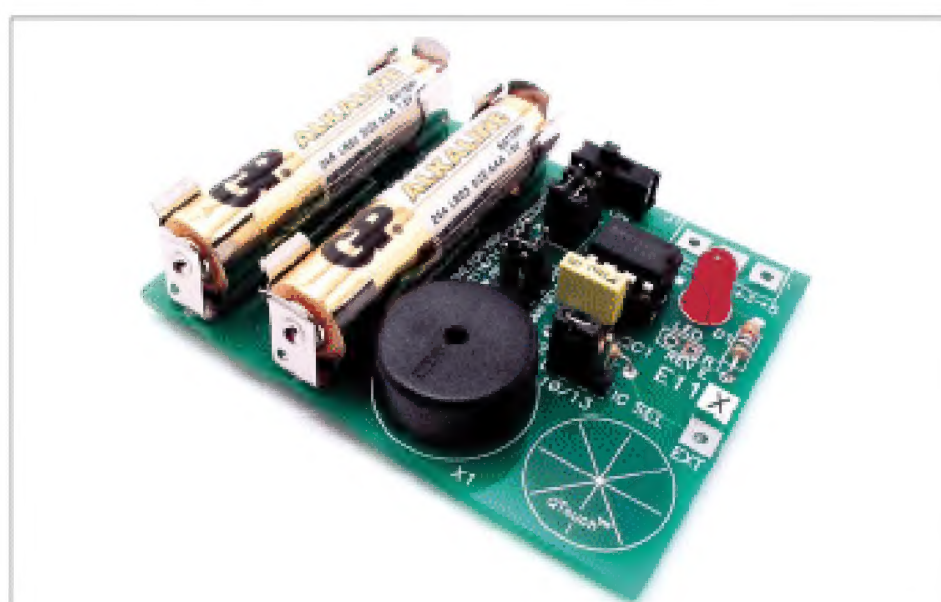


Photo courtesy of Quantum Research Group.

**T**he QTouch™ family of touch and proximity sensors from Quantum Research Group ([www.qprox.com](http://www.qprox.com)) have the ability to sense physical contact through plastic or glass up to 100 mm (4") thick. Even gloves won't

stop QT110, QT111, QT112, QT113, QT115, and QT118H from detecting a touch. Even better, QT113 and QT118H are also able to sense moisture. So sweaty hands, beware.

The QT11x family of chips are as easy to use as they are inexpensive. Just slap an external sampling capacitor on it, add a detecting electrode, and zap it with around +3V and you have the perfect touch sensor. Furthermore, the chips all feature auto-calibration, drift compensation, and automatically calibrate themselves after a time out.

As for applications, QT11x chips are found in a wide variety of commercial, real-world devices from pay machines to door actuators. QTouch chips really shine in sampling for the presence of water, or, as an actuator switch embedded in a receptacle for receiving outside input without having to drill a hole in its exterior.

If you're looking for a painless way to experiment with the QT11x family of touch sensors, then look no further than Quantum's E11x QTouch™ Evaluation Board. Like so many other manufacturer evaluation boards, the E11x is loaded with lots of powerful features for allowing you to fully experiment with touch sensitivity sensors. Both visual and audio touch indicators are included with the E11x and you can easily plug your own external electrode into the board. Oh, and an electrode can be nothing more than a piece of metal foil or a loop of wire. All of this and more for less than \$20 from Digi-Key.

## Computers and Networking It's Sony Time for Europe and Germany

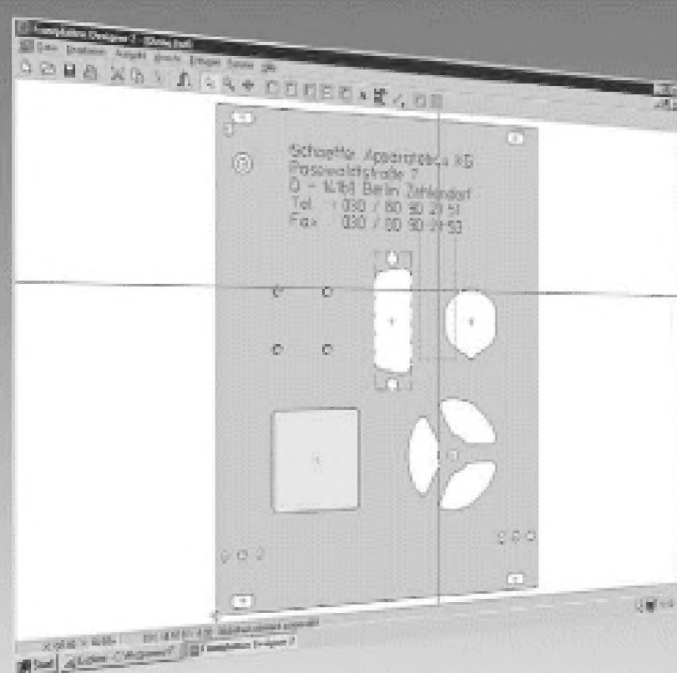


Photo courtesy of SCEE.

**O**n the 76th anniversary of the German invasion of Poland, Sony Computer Entertainment Europe (SCEE; [www.scee.com](http://www.scee.com)) will unleash the PlayStation® Portable (PSP™) on Europe, September 1, 2005. Packaged in a Value Pack system configuration similar to its North American cousin, the European Value Pack will retail for 249 EUR. If you're like most hackers, then you must think that the Sony PSP is a treasure trove just waiting for the right solder-

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ing iron. Well, I've got the right soldering iron and I spent the entire summer hacking the brains out of the thing. If you'd like to learn more about how you can exploit your own PSP, just wait until my book *PSP Unplugged* (McGraw-Hill, 2006) is released early next year. Please wait, pretty please.

## Circuits and Devices It's ALIVE



**R**un, don't walk, into the jungle for the latest innovation from WowWee — WowWee Alive! Chimpanzee ([www.wowwee.com](http://www.wowwee.com)). Developed by Hollywood F/X expert George York, WowWee Alive Chimpanzee employs a new cutting edge technology for replicating the sounds and movements of nature called Facetronics™.

Sporting all of the features that we've come to expect from a WowWee toy — sound sensors, touch sensors, and IR vision — the Facetronics Chimpanzee has something no other toy currently has — mood swings. Who can argue with the people that fused “personality and technology?” Better yet, WowWee Alive has come up with one of the best advertising lines in this year's toy race — “this chimp is so real, it's unreal.” That's enough for me, I'll take a couple for Halloween, please.

## Welcome to the ZigBee Follies

**F**reescale Semiconductor ([www.freescale.com](http://www.freescale.com)) makes a great Developer's Starter Kit (DSK) for

experimenting with 802.15.4 ZigBee wireless technology. Consisting of two reference design boards equipped with accelerometer sensors, MC13192 2.4 GHz RF transceiver data modems, and MC9S08GT60 microcontrollers, the DSK includes all of the software, documentation, and even a trial version of Metrowerks CodeWarrior™ IDE that is needed for building and testing

a ZigBee design. Reasonably priced at under \$200, the 13192DSK is a great way to evaluate ZigBee. Let's take a look at each of the DSK's major components in greater detail.

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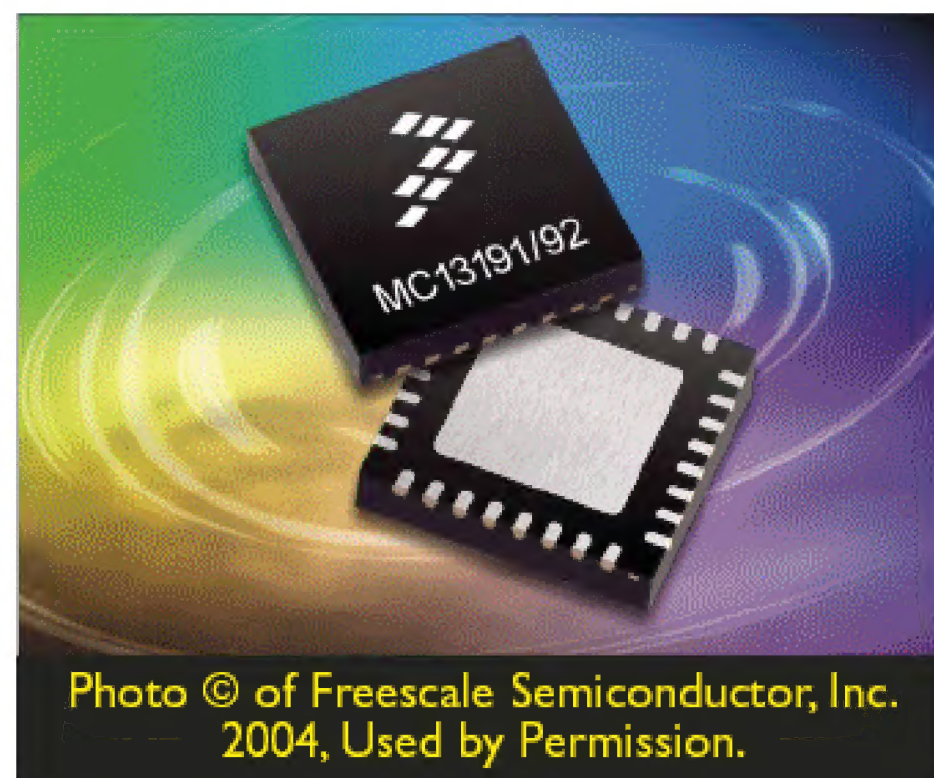


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2. MMA1260D Z-Axis 1.5g Accelerometer. A small package 1200 mV/g sensitivity along the z-axis.
3. MC13192 2.4 GHz RF Data Modem. This packet modem is compliant with IEEE 802.15.4.
4. MC9S08GT60 Microcontroller. A low-power, low-voltage eight-bit MCU.

What can you do with this sucker? First of all, one of the boards is set to being a transmitter, while the other one becomes the receiver. It's a no-brainer: the one connected to your PC is the receiver and the remote board is the transmitter. After you load some demo software, you are ready to become a data logger.

## Industry and the Profession Satisfy Your (Inner) Kid

Some of my best electronics hacks come from stalking, err, strolling the aisles at my local toy store. Imagine all of the great info that you could glean from attending the Chicago International Toy and Game Fair ([www.chitag.com](http://www.chitag.com)) on Navy Pier in Chicago, IL over the Labor Day weekend, September 2-4, 2005.

## Home Theater Know How

Got a hankering to learn more about topics like home theater installation techniques? Look no further than Custom Electronic Design and Installation Association (CEDIA) EXPO 2005 ([www.cedia.net/expo](http://www.cedia.net/expo)). CEDIA EXPO 2005 will be held at the Indiana Convention Center and RCA

Dome from Wednesday, September 7 through Sunday, September 11.

## It's a Wrap

If you do any kind of digital printing, then you know all about the Seybold Chicago Conference ([www.seybold365.com/chicago/](http://www.seybold365.com/chicago/)). Set for September 11-14, 2005 at the Hyatt Regency McCormick Place tutorials for digital publishing workflow and asset management will be given.

## It's in There, Some Place

COMP Media's Embedded Systems Conference Boston ([www.esconline.com/boston/](http://www.esconline.com/boston/)), is an educational forum geared towards engineers and engineering managers who develop embedded systems. Being held September 12-15, 2005 at the Hynes Convention Center, this year's Embedded Systems Conference is co-located with the Embedded Security Seminar.

## Peddling the Tour de Apple

Gee, what could be better than attending Apple Expo 2005 ([www.apple-expo.com](http://www.apple-expo.com)) in Paris, France on September 20-24, 2005? Held at the Porte de Versailles, this expo will feature a new Japanese robotics pavilion along with the now overused Weblog (aka Blog) and Podcasting technologies. If I promise to bring back a bottle of wine, may I please attend as a *Nuts & Volts* reporter? Please?

## Wired on Wireless

What isn't wireless these days? For that matter, who hasn't gone wireless? You can find out answers to these and lots of other questions at CTIA WIRELESS I.T. & Entertainment 2005 ([www.ctia.org](http://www.ctia.org)), September 27-29, 2005 at Moscone West in San Francisco, CA. Both enterprise and consumer solutions for integrating wireless technologies into the real world will be available for your drooling over. **NV**



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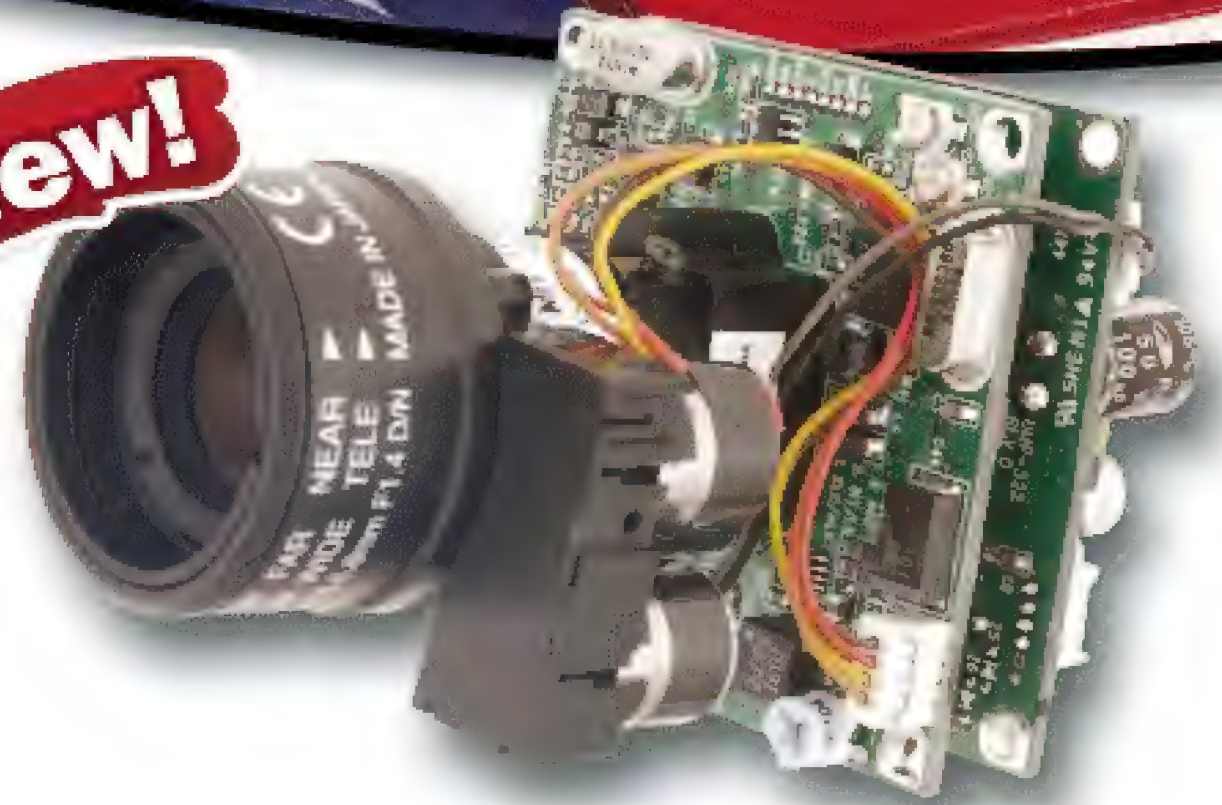
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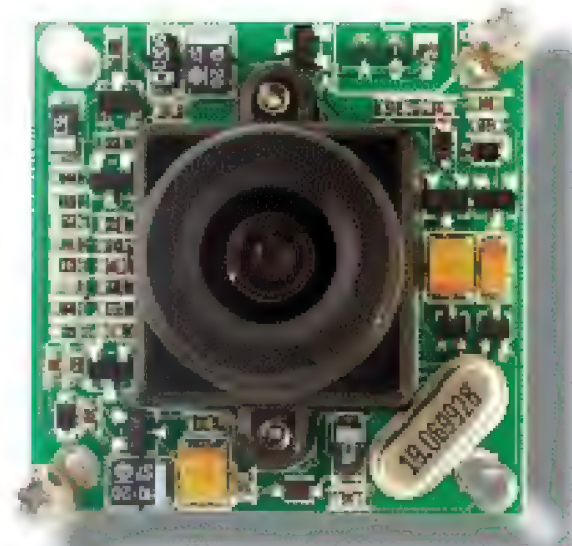
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# Electronics Q&A

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, comments and suggestions.

You can reach me at:  
[TJBYERS@aol.com](mailto:TJBYERS@aol.com)

## What's Up:

A bunch of magic. I can make FM carriers disappear, colored lights appear, and create a magic wand under the hood of your car. Well ... almost. What I really do is describe FM transmissions, build a magic box and show you how to gauge the power in your RC battery package. A reader has a unique test instrument, too.

## SCA ... On the Air

**Q** Lately, I've been experimenting with SCA adapters: a kit from a 1960 *Popular Electronics* article, one from another magazine article, and a kit from Ramsey. I have found that they all work with some receivers and none will work with other receivers — receivers that, to me, appear to be quite similar. I don't have a lot of FM test gear and can't seem to put my finger on the difference. Any pointers? How about an SCA adapter schematic?

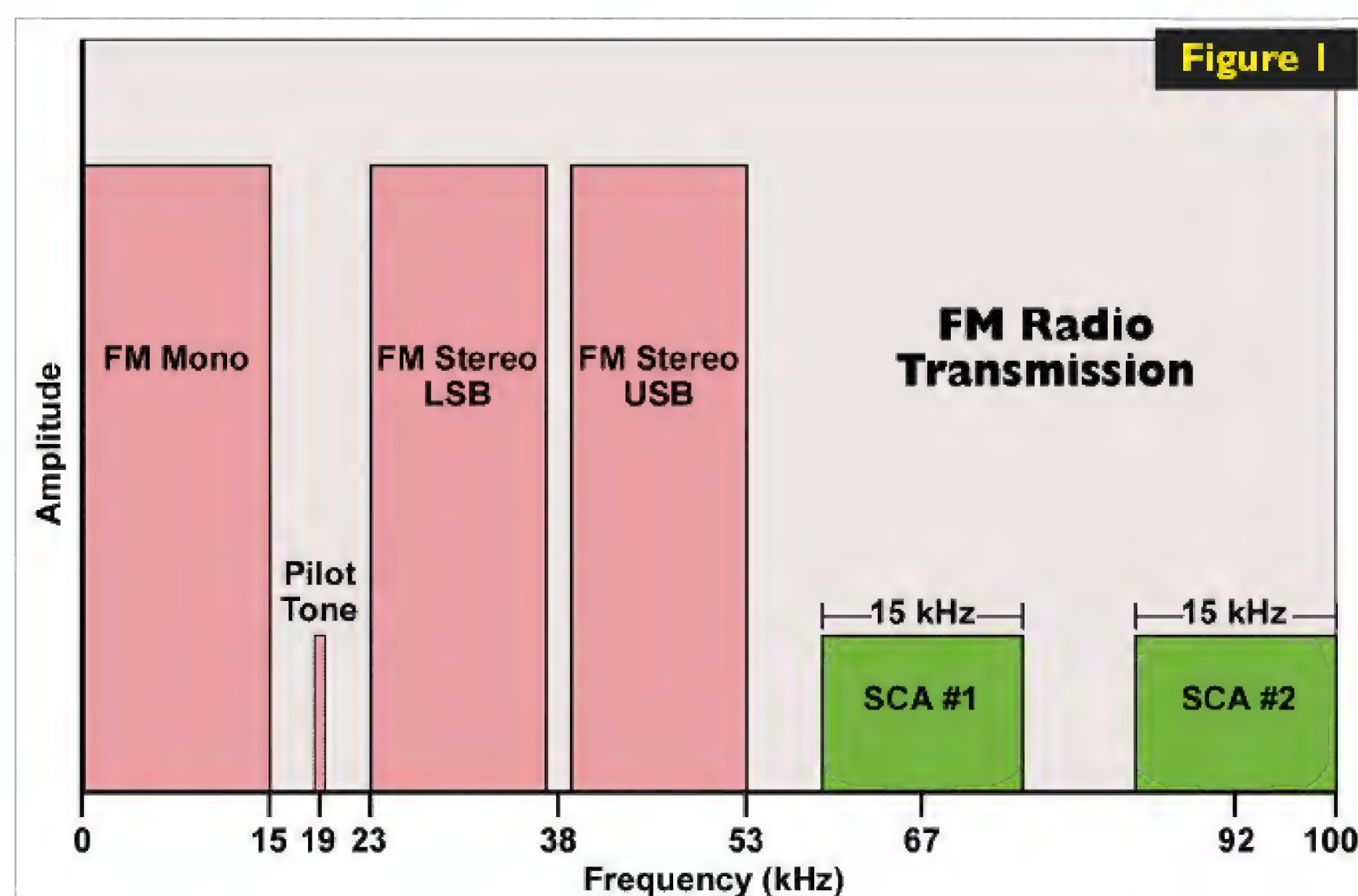
**David Herman**  
 Laurel, MT

**A** Let's first define SCA — Subsidiary Communications Authorization. The FM channel is 150 kHz wide ( $\pm 75$  kHz). Within this bandwidth, the broadcast station inserts a mono and a stereo signal, with appropriate decoding tones at 19 kHz and 38 kHz (which is actually a suppressed carrier). This leaves about half the bandwidth free for something else.

FM stations are allowed to place

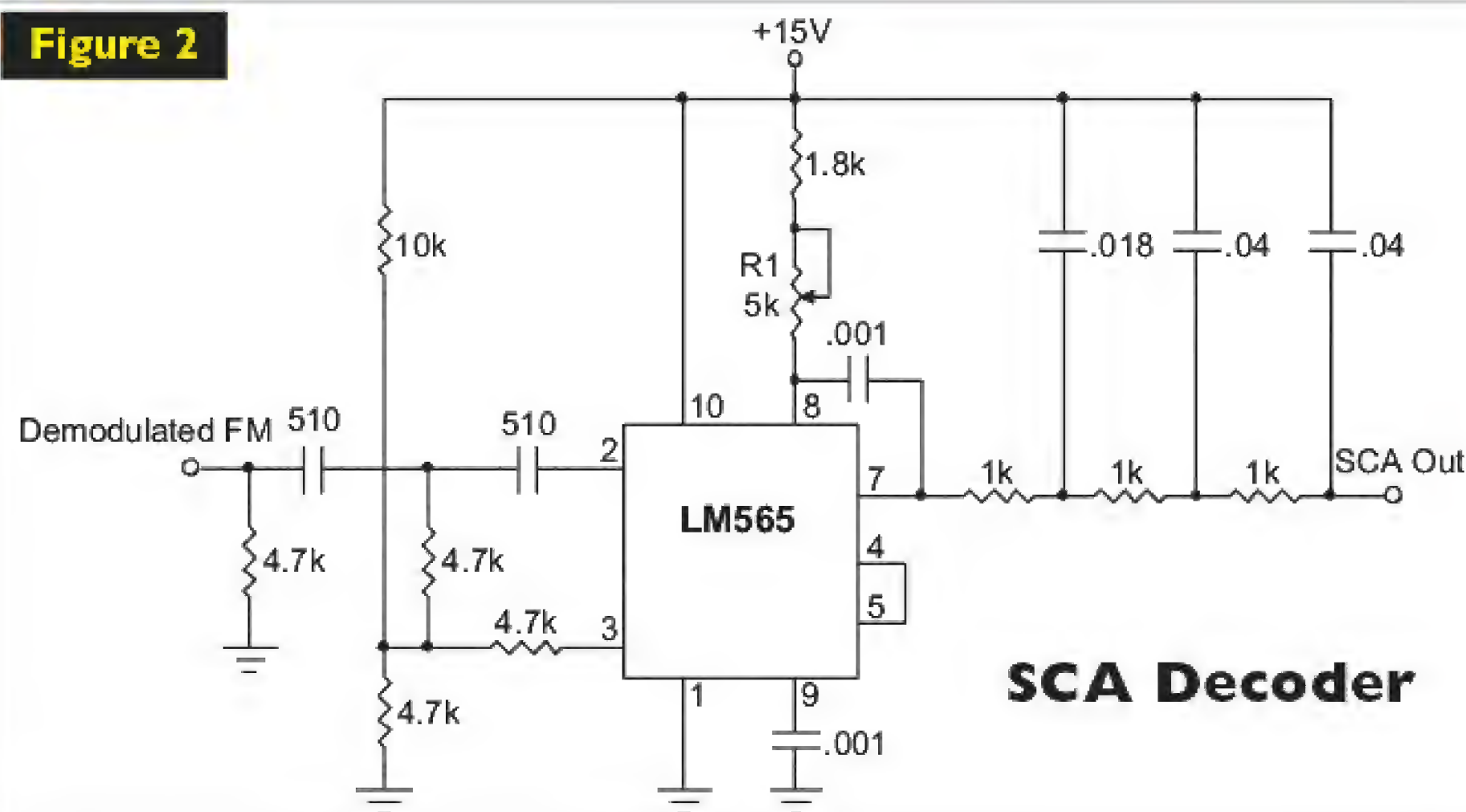
other subcarriers in the unused portion of the spectrum to transmit other information, like subscriber background music, foreign language services, or stock market quotes. Usually there are two subcarriers, one at 67 kHz and one at 92 kHz (Figure 1). Data transmissions sometimes use 71 kHz, although other frequencies may be used, too. The subcarriers are limited only by the bandwidth of the allotted frequency slot. To receive SCA transmissions, you need an FM receiver and an SCA decoder. Any FM receiver will do. It doesn't have to be stereo. However — and this is a big however — the SCA signal won't be available if the radio's audio output is filtered to cut out frequencies above 15 kHz (common in cheap receivers). If this is the case, you have to open up the radio and tap off the audio before filtering — preferably just after the detector.

Most SCA decoders today use a phase-locked loop (PLL), like the LM565. A very simple SCA decoder built around a LM565 (then the SE565) appeared in a Signetics





**Figure 2**



Applications Manual (Figure 2). A more robust circuit can be found at [www.uoguelph.ca/~antoon/gadgets/pll/pll.html](http://www.uoguelph.ca/~antoon/gadgets/pll/pll.html)

## FM Modulation

**Q** I have a question about FM transmission. In AM transmission, the sidebands give some of their power to the carrier. In FM transmission, sidebands steal some of the power from the carrier. And there are times when the carrier becomes zero. My question is, what is really going on here? Are you still transmitting signal or are you not because the carrier is zero? And, is there any significance to this when your carrier becomes zero?

**Julius B.**

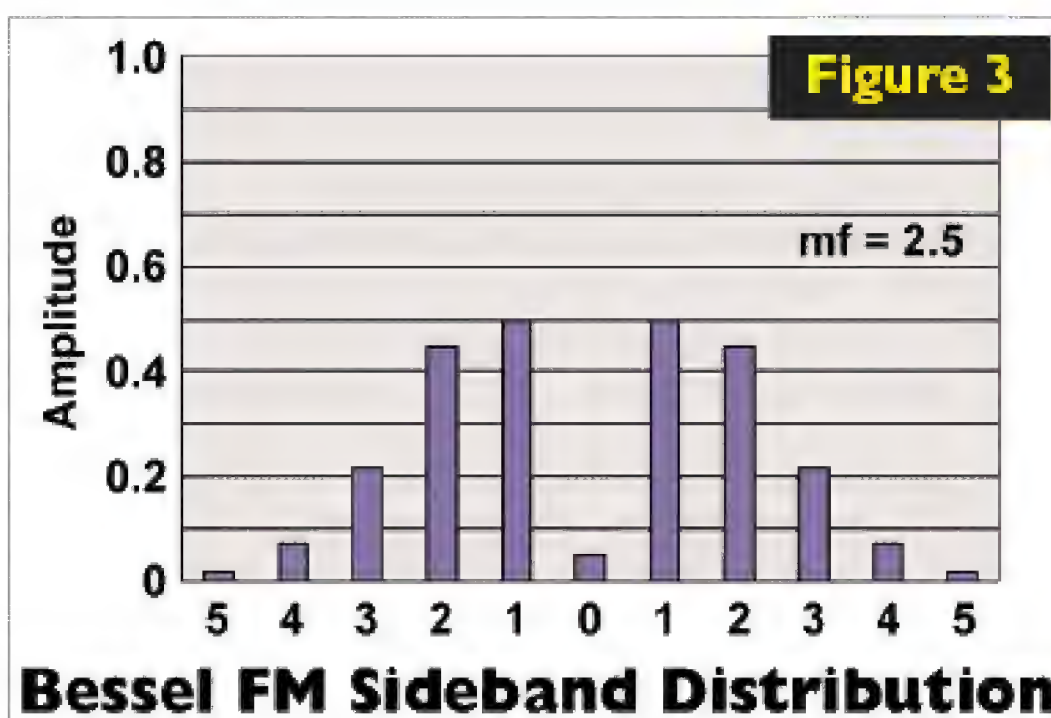
**A** This is a difficult question to answer without going into a lot of math, but I'll try. First, yes, you are still transmitting a signal even if the carrier goes to zero. That's because the signal strength is contained in the sidebands. Unlike AM modulation — which imparts information by varying the power output of the carrier wave — FM modulation encodes information by changing the frequency of the carrier. FM sidebands are the frequencies — plus and minus — that exist on each side of the carrier frequency.

Sidebands are created when the carrier is modulated. In the US, the bandwidth is defined as

$\pm 75$  kHz — resulting in a bandwidth of 150 kHz. Well ... kinda. A 75 kHz FM broadcast signal requires a little more bandwidth for a host of reasons, including station spacing and the modulation index.

As in AM modulation, the sidebands are separated by the modulation frequency from the carrier. However, depending on the modulation index, the sidebands vary in amplitude. They appear, reach a maximum, then — at higher modulation indices — some sidebands disappear altogether. In fact, the carrier disappears at a modulation index of 2.4. This means that, if you apply a 31 kHz tone to an FM carrier and adjust the level of this tone to produce a deviation of 75 kHz, the carrier will actually null out.

No, the FM signal has not disappeared. All of its energy is now contained in sidebands spaced at 31 kHz increments from the carrier, i.e., 31 kHz, 62 kHz, 93 kHz, etc. They are, I must add, decoded equally in terms of power by the receiver because it



**Figure 3**

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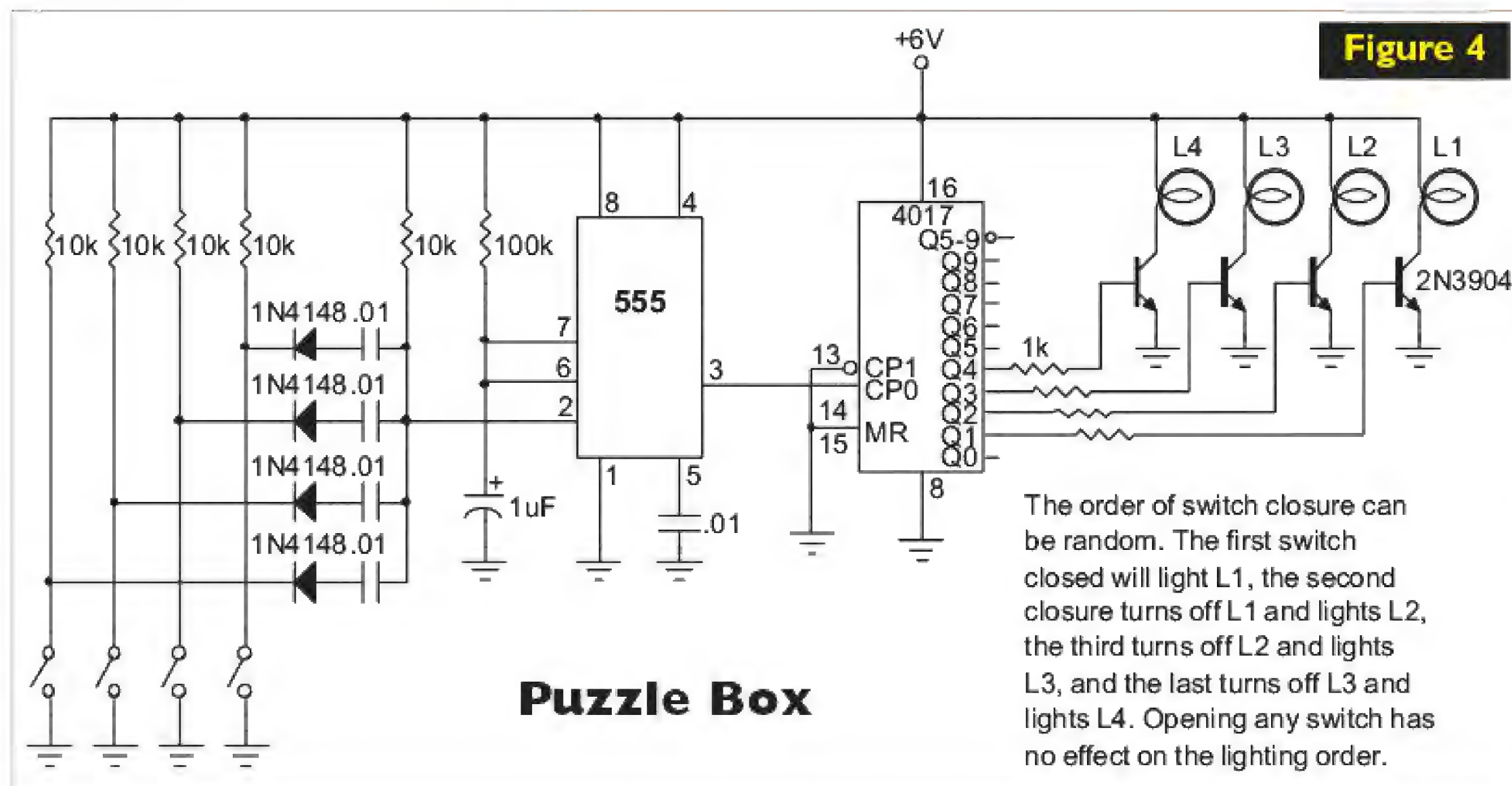
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that there is always a sequence to the bulbs. That is, the first switch closed always lights bulb #1, no matter what color it is. The next switch closure lights bulb #2. The pattern of switch closure isn't the key, but the order in which the lamps are lighted. Any switch closure can light the next bulb in the sequence. With that in mind, I decided a 4017 would create the ripple effect desired. All that's needed is a single

gathers the entire bandwidth for processing.

FYI, the sidebands vary in amplitude in a pattern that can be expressed mathematically by Bessel functions of the first kind (Figure 3), where  $N$  is the order (carrier  $N = 0$ , first sideband  $N = 1$ , second  $N = 2$ , and so forth) of the Bessel function. The modulation index ( $mf$ ) is 2.5.

## Magic Box

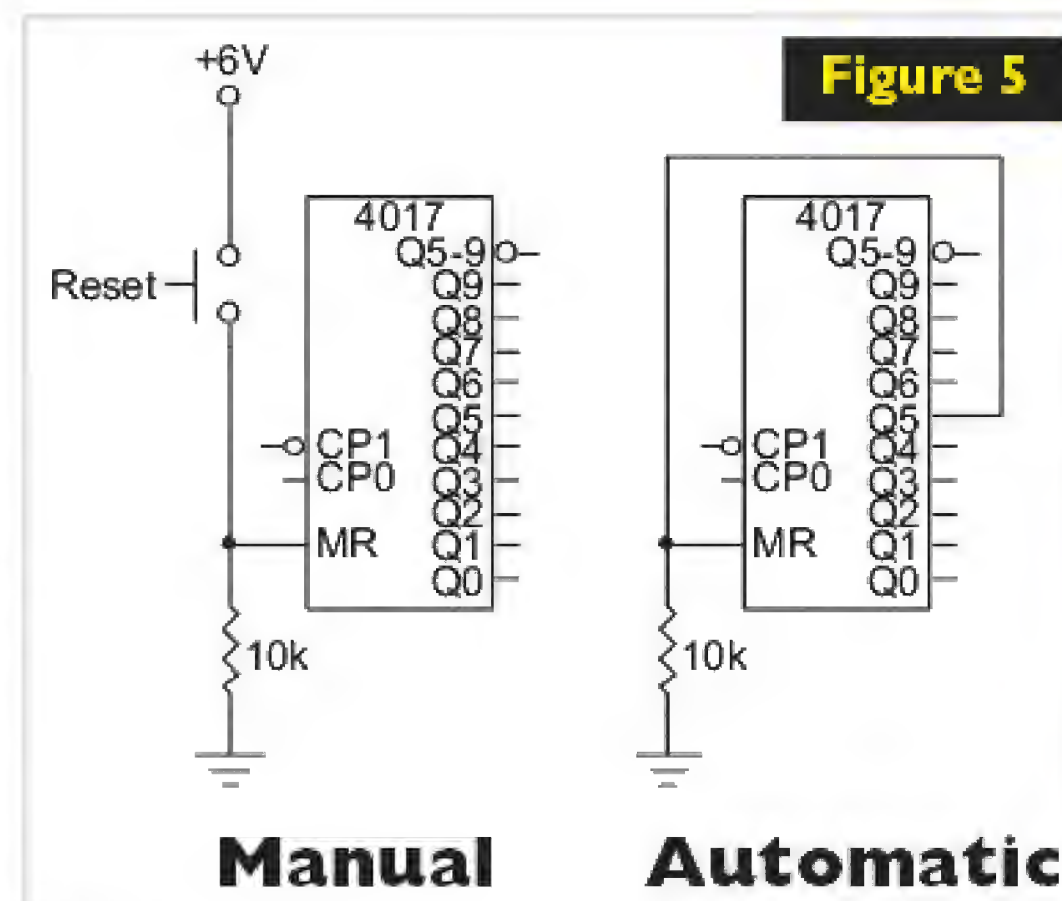
**Q.** I recently saw a fascinating little "black box" puzzle that you might help me solve. It's a wooden "cigar" box with four colored bulbs in four sockets and four toggle switches. The toggle switches have removable covers on their handles that match the colors of the bulbs. If you flip the green switch, the green bulb lights,

the red switch turns on the red bulb, and so forth for the yellow and blue. Now, the interesting part of the puzzle is that if you unscrew the bulbs and move them to different sockets, the colored switches STILL control the corresponding colored bulbs.

To further confuse the observer, if you remove the colored covers on the handles of the switches and swap them around, you find that the newly colored switches STILL control the bulb that matches their color, even though you've done nothing but swap the plastic sleeves over the handles!

All I know about this circuit is that it uses at least one IC, and a couple of flashlight batteries. To my best knowledge, there are no magnetic switches or other hidden devices. It is all done with logic. I would love to build this puzzle box and I hope you can show me how.

**John Seibels**  
Columbia, SC



**A.** This was a new one to me, but once I saw the pattern, it became simple. You told me

pulse for each switch closure. Figure 4 is what I came up with.

The 555 timer generates a pulse each time pin 2 (trigger) goes low — which happens when any of the four switches are closed. The diodes are necessary to prevent interaction between the switches (i.e., a closed switch preventing the negative pulse on the trigger). This pulse advances the 4017 output by one, and lights the corresponding bulb.

Now for the reset. You can either reset the counter by turning it off/on, press a reset button, or have the 4017 do it for you (automatic). The latter two options are shown in Figure 5.

**John Responds:** *Heyyyyyy ..... IT WORKS !! It was fun and educational. I am enclosing a picture of my puzzle box (Figure 6), which was made almost entirely with parts from RadioShack.*

## Magic Wand

**Q.** How complicated would it be to make an inductive probe for car circuits? I'm interested in monitoring a solenoid that's only active at highway speeds; a simple LED on/off indicator is all I need. I really don't want to tap into the circuit, because it requires poking a wire into the connector or cutting the insulation.

**Doug Arndt**





**A** Complicated it is not, but certain conditions must be met. My design assumes that your relay emits an external magnetic field when engaged. That usually means it's encased in plastic, not steel. If this is the case, the magnetic field can be detected with a Hall-effect device — and nothing more.

Well, you do need an LED and current limiting resistor, as shown in Figure 7. When the magnetic field on the hall sensor exceeds a critical amount — typically 300 Gauss — the open-collector transistor turns on. This causes current to flow through the LED and light it. That's it ... almost!

You're going to have to orient the Hall device so that it responds to the magnetic field. This means that you need to energize the relay somehow and run the Hall switch over the coil like a wand (flipping sides) until the LED lights. Then glue it in place. Your next assignment will be finding a suitable Hall-effect device.

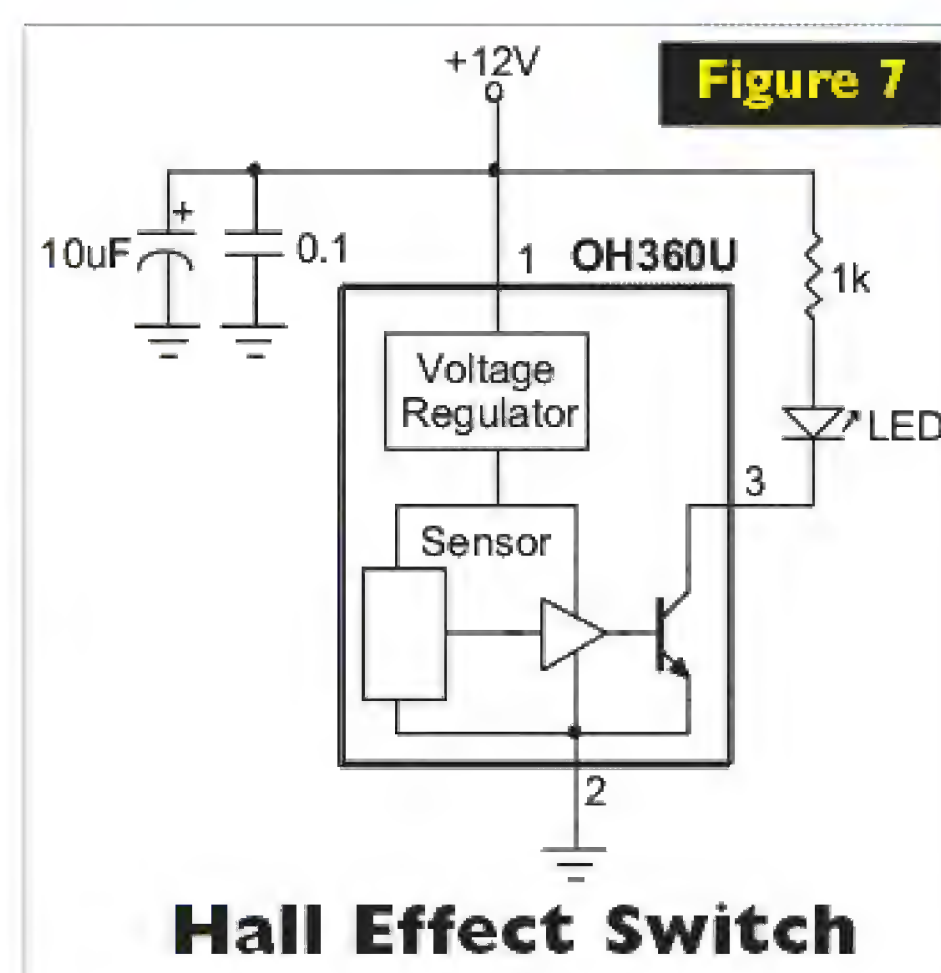
Once plentiful, these sensors are getting harder and harder to find. In fact, Digi-Key (800-344-4539; [www.digikey.com](http://www.digikey.com)) has reduced its stock to just 122 devices, only a handful of which are in stock at any given time. I chose the OH360U from Optek because it meets all the criteria. Other options are the A3122 or A3213 from Allegro Microsystems ([www.allegromicro.com](http://www.allegromicro.com)).

## Audio VU On PC

**Q** Do you know of any software package that will take audio input to the computer and display various sound level graphics on a monitor, e.g., bar graph equalizer, VU meter?

**T. Campbell**

**A** In fact, I do — and I like it a lot. It's called DXVU Meter from xFX JumpStart ([www.software.xfx.net/activex/dxvu](http://www.software.xfx.net/activex/dxvu)). DXVU Meter is an



ActiveX control, which can monitor any audio device configured as a recording source, such as a microphone or CD-ROM, and display the monitored audio levels like a standard VU Meter or as an oscilloscope. DXVU Meter is also able to save the monitored audio data to a WAV file. Other functions include a spectrum analyz-

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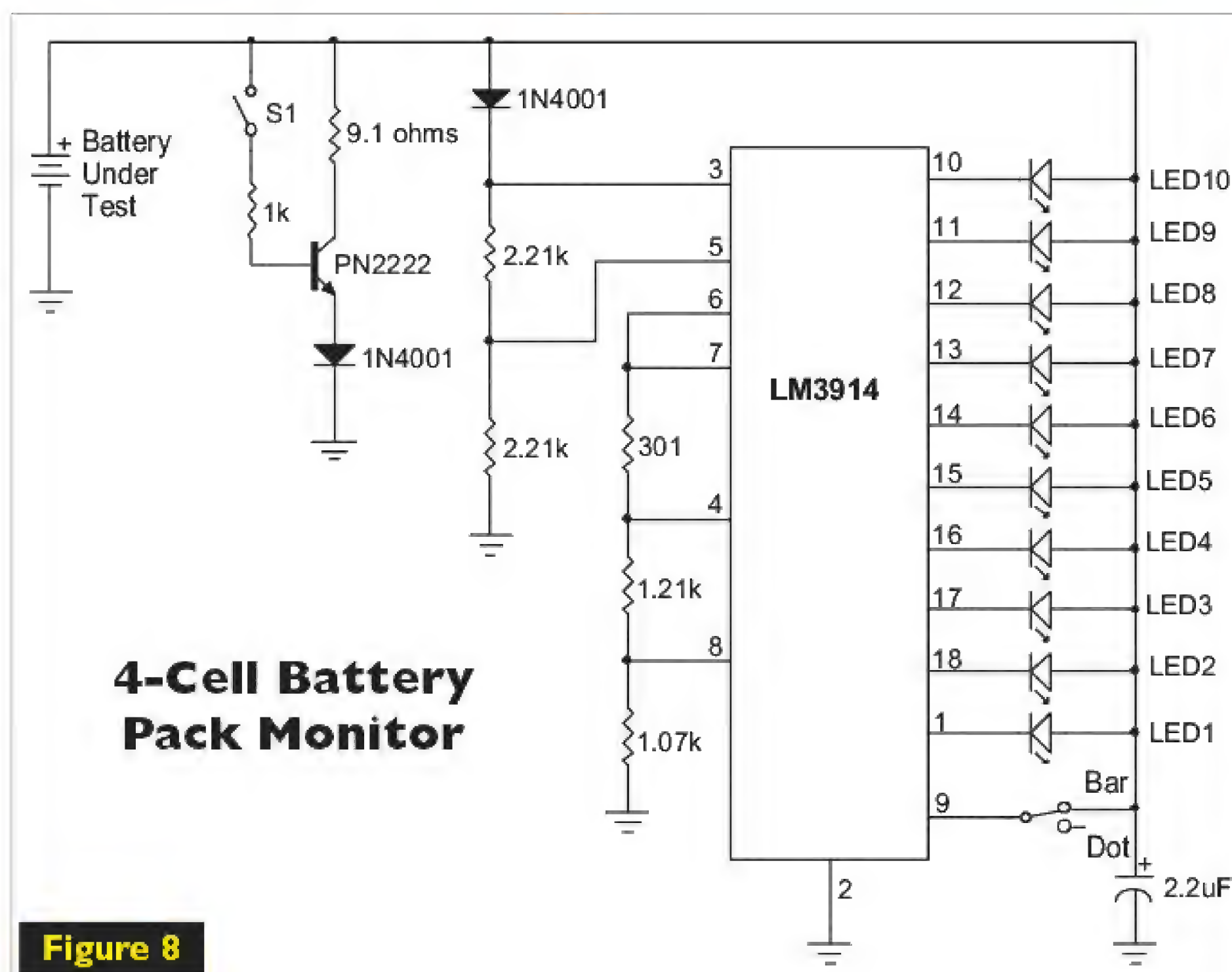
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**Figure 8**

er, a silence stop record, and the ability to resize it to fit into any form design. It's shareware with a \$35 price tag. A demo download is free.

## Power to RC Cars

**Q** I run RC cars, and after a couple of runs, I have no idea of the state of my battery pack charge. I would like to build an LED 3- to 6-volt monitor with low current drain that would indicate how much charge is left. I'm thinking in terms of a row of seven LEDs that indicate voltage lev-

els of 3, 3.5, 4, 4.5, 5, 5.5, and 6 volts.

**Doc**

**A** If I'm not mistaken, most RC cars use NiCd cells in their battery packs. The problem with your approach is that the voltage of a NiCd cell sags a mere 0.3 volts over useful battery life. This makes it almost impossible to interpret the amount of charge using a voltmeter. In a four-pack like yours, that means the voltage would read between 4.9 and 5.0 volts for 60% of the charge.

Fortunately, I ran across a solu-

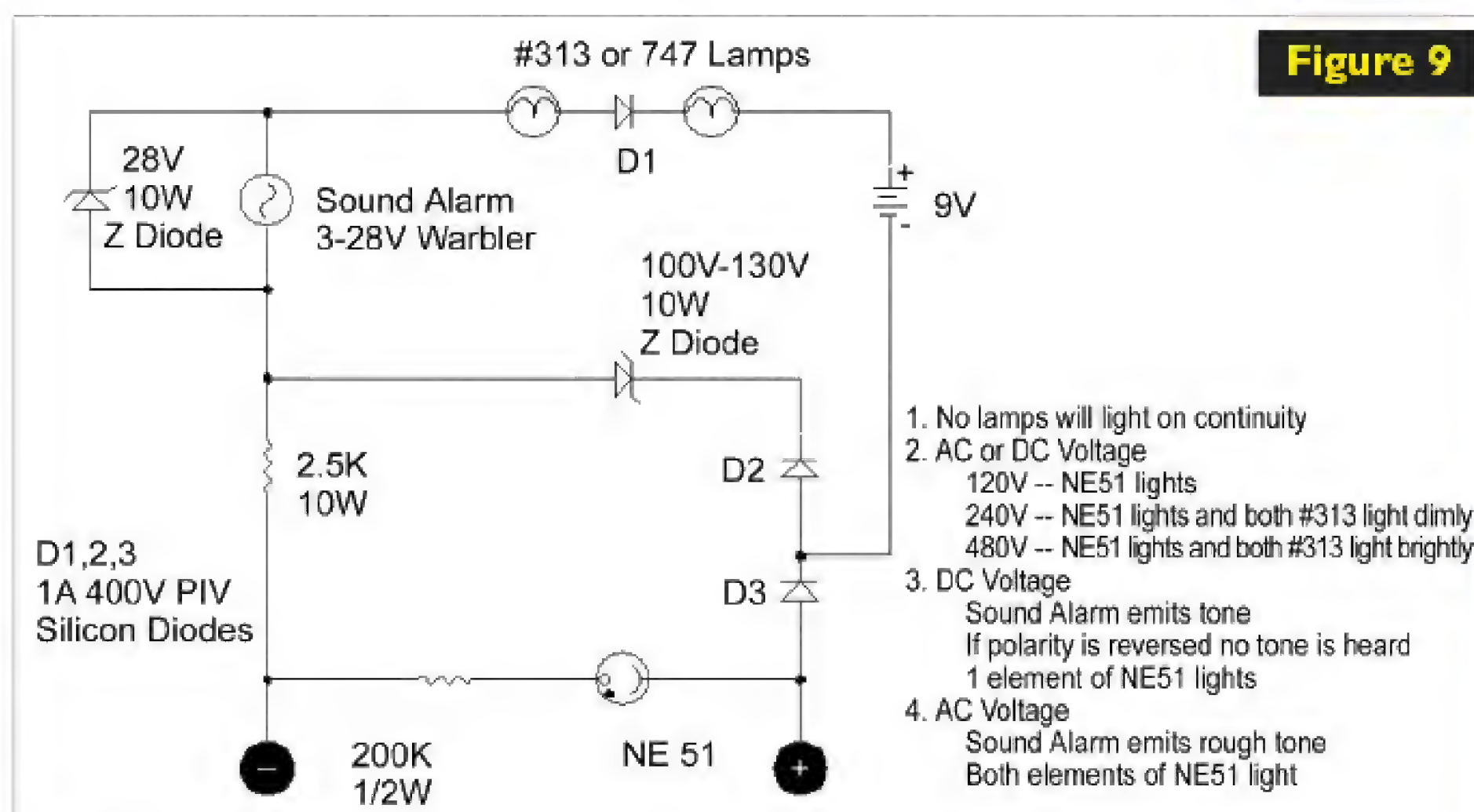
tion from C. Brent Dane called the HOTCHEK ([www.hem.passagen.se/rasmus-modellflyg/elektronik/hotchek.pdf](http://www.hem.passagen.se/rasmus-modellflyg/elektronik/hotchek.pdf)). He tests the charge in an RC battery pack using a novel method of monitoring the battery voltage under a heavy load (closing S1) over time. Basically, the output voltage of a charged pack will drop slightly over about 10 seconds and stabilize. In a battery pack near the end of life, the output voltage will continue to decline without leveling off. Of course, trying to figure the amount of remaining charge during the middle area of charge is no better than an educated guess based on past battery performance. Dane explains it in his website, along with a detailed chart of battery pack types. Meanwhile, here is his schematic — Figure 8 — almost. I removed one resistor (pin 1) and added a capacitor.

**Editor note:** When I received my copy of the July 2005 issue, I discovered a feature called "Battery Analyzer for RC Power." It's a little complex, but an ideal way to profile your battery pack. — TJ

## READER CIRCUIT: Multi-Purpose Tester

I was given this schematic (Figure 9) over 30 years ago for a combination voltage and continuity tester. I built it and found it so useful I'd like to pass it along. It uses a Sonalert for continuity. It uses neon lights and the Sonalert to signal voltage from 110-480V AC and DC. Nothing has to be done to go from continuity to voltage.

**Richard E. Woods**  
Cleveland, OH



1. No lamps will light on continuity
2. AC or DC Voltage
  - 120V -- NE51 lights
  - 240V -- NE51 lights and both #313 light dimly
  - 480V -- NE51 lights and both #313 light brightly
3. DC Voltage
  - Sound Alarm emits tone
  - If polarity is reversed no tone is heard
  - 1 element of NE51 lights
4. AC Voltage
  - Sound Alarm emits rough tone
  - Both elements of NE51 light

## Cool Website!

Penton Media's magazine *Electronics Design* has linked up with Discover Circuits' website to offer more than 11,000 schematics cross-referenced into 500 categories. There are also design and resource links, product reviews, and more.

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# Micro Memories

## The Computer That Took Man to the Moon

**E**ven though the last *Saturn V* flew some 30 years ago, the Apollo moon landings remain one of mankind's greatest engineering efforts. What makes them even more impressive was the era in which they were designed.

During the 1960s, computers occupied whole rooms, but had less power than the PC now sitting in the den of your home. There weren't even pocket calculators back then. And yet, on September 12, 1962, in front of a packed crowd in Rice University's football stadium, President Kennedy was willing to propose the building of "a giant rocket more than 300 feet tall, the length of this football field, made of new metal alloys, some of which have not yet been invented, capable of standing heat and stresses several times more than have ever been experienced, fitted together with a precision better than the finest watch."

At the top of the *Saturn* was the Apollo spacecraft. And one of the

most important components inside of the *Saturn* was its guidance computer. As Charles Murray and Catherine Bly Cox noted in their seminal classic *Apollo: The Race to the Moon* (Simon & Schuster, 1989), "The computer capacity of the mainframes in the Control Center [of NASA's Manned Spacecraft Center in Houston] was smaller than that of the desktop systems of the 1980s, and onboard computers in the command and lunar modules had less capacity than some pocket calculators."

### Overflowing the Boxes

"Overflow the boxes" was NASA-speak for putting in more requirements than computer memory and computing capacity could handle. That wasn't very difficult with the Apollo Guidance Computer (AGC), which in retrospect looks pitiful in comparison to today's Windows XP-equipped PCs with their GHz of memory, 3 GHz processors, and 300 GHz hard drives.

In contrast, the Apollo Guidance Computer, which weighed 70 pounds, had only 36K of RAM and

2K of ROM. But it was able to guide 27 men to the moon's orbit and bring them back safely. It consisted of two parts: a small keyboard for the astronauts inside the command and lunar modules, and a separate, slightly larger logic unit.

The AGC was built by Raytheon and used approximately 4,000 discrete integrated circuits from Fairchild Semiconductor. (There were also two other onboard computers on a moon mission — a flight computer onboard the *Saturn V* booster rocket, and a separate backup computer on the lunar module that could be used in an emergency for a liftoff from the moon should the AGC fail.)

The limitations of the Apollo Guidance Computer resulted in some classic push-pull arguments from Apollo's flight controllers and engineers trying to fit routines too complex into the limited capacity of these computers. Murray and Cox quote Cliff Charlesworth, one of Apollo's flight directors, as saying, "Every time we'd get a new capability in the computer systems, the flight controllers would start laying their requirements on it. In short order, we'd overflow the boxes. And [Chris]

Kraft [NASA's legendary first flight director] would get mad. He'd say, 'Goddammit, get it back to where it'll fit, we can't get any more computers!'"

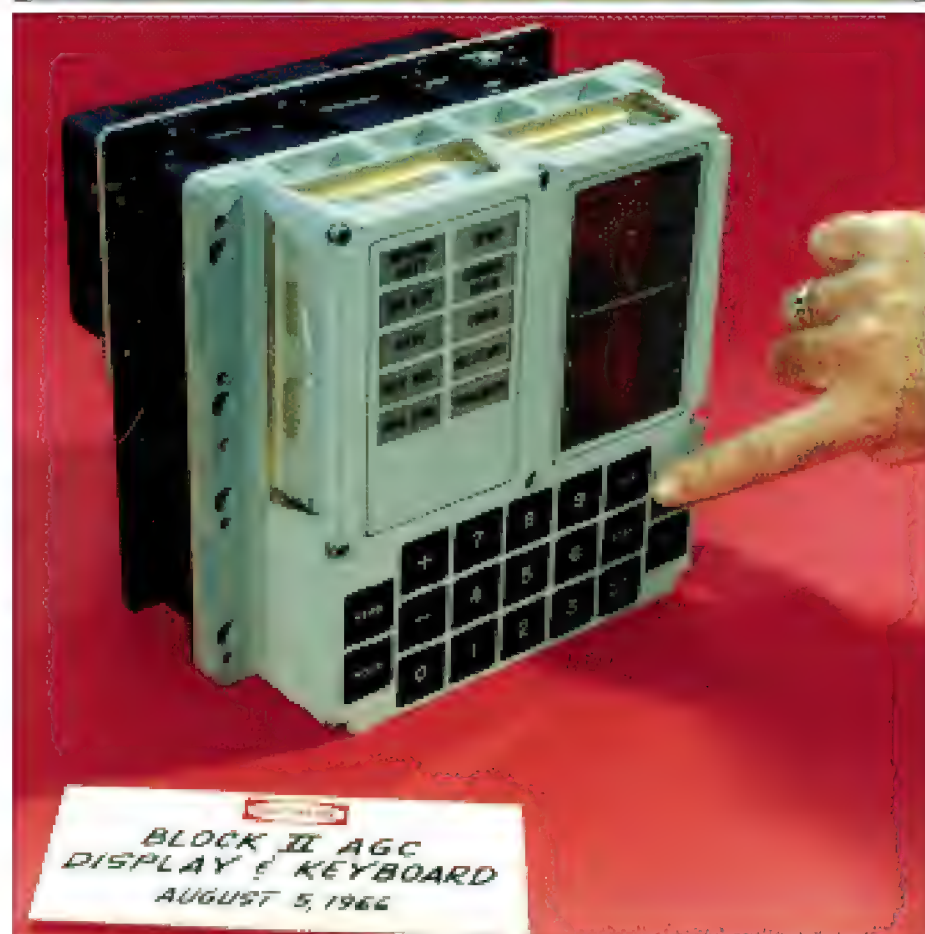
### Built Under an Intense Deadline

Like all aspects of the Apollo

#### NOTE

All photos are courtesy of the Computer History Museum.

The "Block 2" version of the Apollo Guidance Computer, designed in 1966, increased erasable memory from 1K to 2K words. Fixed memory was expanded from 24K to 36K.



Apollo scanning telescope and sextant.





program, the computers were created under intense pressure: Kennedy's "We choose to go to the moon in this decade" speech in 1962 gave the program a firm deadline, and the memories of his assassination a year later only increased the weight of his words. In contrast to later decades, the NASA of the 1960s was that rare government program with both a purpose and a deadline, as well as a burning collective desire to get the job done.

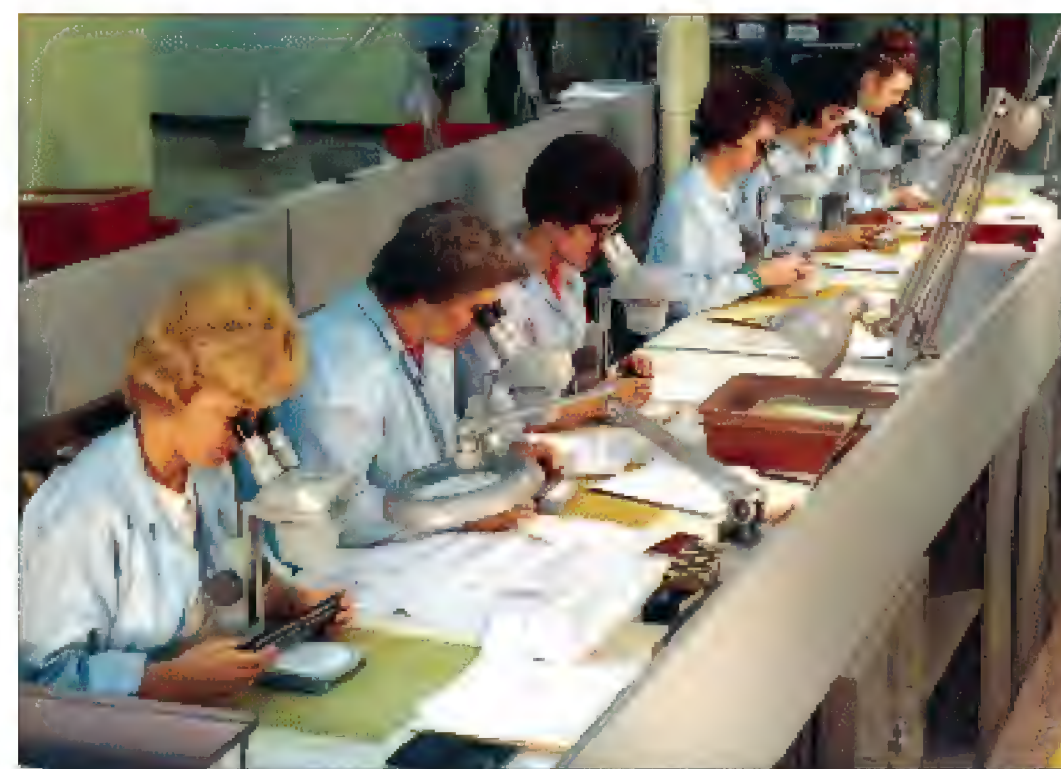
In 1961, during the very early stages of the design of Apollo and its Saturn booster, NASA contacted MIT to study the feasibility of a digital control system for Apollo. According to, Dag Spicer, the senior curator of Silicon Valley's Computer History Museum ([www.computerhistory.org](http://www.computerhistory.org)), the driving force behind the design of the Apollo Guidance Computer was a cyberneti-



Charles Stark Draper and Werner von Braun in front of the Apollo Guidance Computer.

cist at MIT named Charles Stark Draper, for whom the university named a laboratory devoted to studying and measuring motion.

Draper and the men under him cut their teeth working on the Poseidon and Polaris guided missiles. "His expertise was basically how to point missiles and make them go where you wanted them to go" Spicer



Raytheon employees assemble the first Apollo Guidance Computers, circa, 1962.

says, adding, "It was very Cold War research-related: how do you make guidance systems that allow bombs to get as close to their targets as possible." This makes sense because, as Spicer notes, "You know, a rocket is just a missile with a person on top; it's basically all the same technology." (In the early 1970s, MIT succumbed to the anti-war protestors of the time

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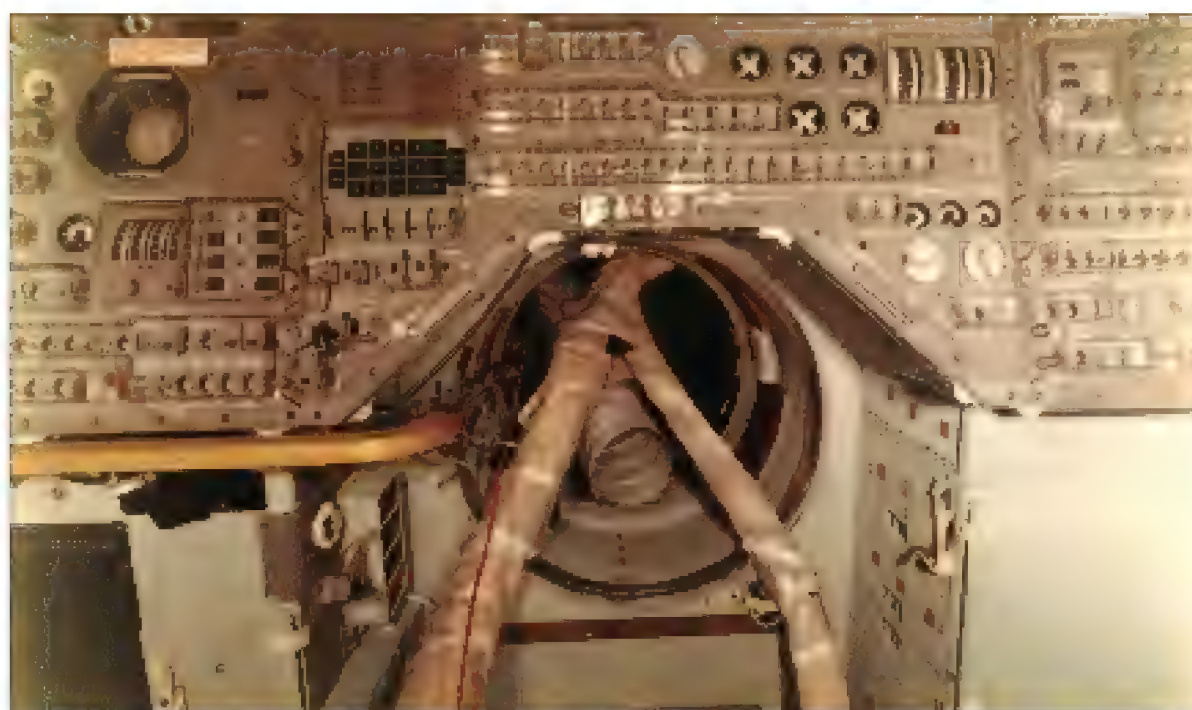


Eldon Hall, who taught at MIT until 1988, designed much of the hardware for the Apollo Guidance Computer, helping to pioneer the use of integrated circuits in its design.

and spun the Draper Lab off as a separate non-profit entity.)

The Gemini program, which directly preceded Apollo, involved the first American manned attempts at finding a fixed target in space and navigating towards it. To say that these first efforts were challenging is an understatement. The great untold story of Gemini is one of how many things went wrong, but were salvaged in real time, during this thoroughly experimental phase of the space program.

In addition, the complexity of finding, orbiting, and returning from a celestial body that orbits over 200,000 miles from planet Earth added a whole new set of difficulties to space navigation. The Apollo program is not only a tribute to the



Inside the Apollo capsule. The Apollo Guidance Computer is located to the upper left of the crawlway tunnel.

astronauts who actually flew the missions, but also to the engineers and flight controllers who designed their hardware and guided them to their target and then back home.

## By 1969, Less Powerful than Business Computers

As trade publications observed at the time of Neil Armstrong and Buzz Aldrin's 1969 landing on the moon, Apollo's guidance computer was even less powerful than computers commercially available at the time, such as DEC's PDP-11. Ironically, this phenomenon is a frequent byproduct of long-term, government-funded projects. Spicer says, "By the time that you've nailed down the project definition and the various technical requirements, and you've decided on an implementation technology, that technology has already changed! By the time that you've actually finished the project, the hardware is usually very outdated."

Spicer notes that outdated computing hardware is, perhaps somewhat paradoxically, "a feature of space programs," adding, "These billion-dollar satellites and spacecraft end up going into space with computational power that's the equivalent of a Commodore 64 or something along those lines. Very small memories, eight-bit processors, very few if any rotating or moving parts. That's one of the lessons of Apollo — to throw out as many parts as you can to keep them out there. The chips

were so expensive as well, which was also a great motivator to cut out parts." Spicer is fond of Gordon Bell's quote, which is directly applicable to the Apollo Guidance Computer: "The most reliable components are the ones you leave out."

Reliable is a good word for the AGC. In 2001, Spicer wrote a

superb article on the guidance computer for *Doctor Dobbs' Journal*, in which he noted that the guidance computer in the *Apollo 11* LEM recovered from a data overload during its lunar descent, and operated just fine on *Apollo 12*, despite the fact that its *Saturn V* launch vehicle was struck by lightning 36 seconds into its ascent. "As every module in the AGC was 'potted,'" Spicer wrote, "that is, dipped in a waterproof epoxy compound to protect it in space, there was great pressure on the software team to be especially dedicated to error-free development."

## Apollo Directly Drove IC Development

Of course, one reason why commercially available computers of the late 1960s were as powerful as they were — a phenomenon that would continue to grow exponentially — was the space program itself. In his article, Spicer wrote, "It's a frequently cited truth that the space program resulted in the accelerated development of integrated circuitry."

Spicer directly credits the Apollo Guidance Computer "more than any other single part of this program" with driving IC development. Considering the staggering advances that personal computers have made since the mid-1970s, it's worth thinking about how they arrived on our desk — and that the Apollo Guidance Computer was a direct forerunner. **NV**

### Visiting the Museum

The Computer History Museum is located at:

1401 North Shoreline Blvd.  
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Fax: 650-810-1055

Email: [info@computerhistory.org](mailto:info@computerhistory.org)  
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Electronic Theories and Applications From A to Z

# Let's Get Technical

## Making the Illusion Real

### Listing 1

```

` Blink five LEDs in different patterns

tick    var    byte
rot      var    word
led      var    word
num      var    word
patt     var    byte[5]
poff     var    byte[5]
counts  var    byte[5]
pon      var    byte[5]
state   var    byte[5]

Start:
` Initialize off/on tick counts
  for Led = 0 to 4
    counts[led] = 0
    random num
    if (Num // 10) > 5 then
      patt[Led] = 1
    else
      Patt[Led] = 0
    endif
    if patt[led] = 1 then
      random num
      poff[led] = num // 16 + 1
      random num
      pon[led] = num // 16 + 1
      low led
    else
      high led
    endif
  Next Led

` Begin one second of rotation
  for rot = 1 to 20

` Perform 128 ticks of activity
  for tick = 1 to 128

` Examine / adjust state of each LED
  for led = 0 to 4
    if patt[led] = 1 then
      counts[led] = counts[led] + 1
      if state[led] = 0 then
        if counts[led] = poff[led] then
          high led
          state[led] = 1
          counts[led] = 0
        endif
      else
        if counts[led] = pon[led] then
          low led
          state[led] = 0
          counts[led] = 0
        endif
      endif
    endif
  next led
  next tick
next rot

Goto Start      ` Repeat forever
End

```

In my last article, I challenged myself to duplicate the interesting patterns created by five small LEDs mounted on a spinning disk (Figure 1). My three-year-old daughter does not know that I have taken her \$10 toy apart to assist in my investigation, so I may end up in a miniature doghouse (or possibly even Clifford's) if I cannot get the original device, or my creation, working.

I decided to use the PIC 16F628 microcontroller in my design. This was a challenge, since I had never before worked with a PIC, written code for the device, or tried to program one. After obtaining an EPIC programming board from Jameco Electronics, along with a batch of 16F628s, it took me about 30 minutes to get an LED flashing on a protoboard. Then I had to think about how to flash five LEDs at different rates, with the rates changing randomly.

First, I watched the original toy again, trying to get a handle on several properties: how fast the disk was spinning; how many times a single LED flashed during a single rotation; and how often the patterns changed. If I could have videotaped the toy and watched the LEDs flash in slow motion, I could learn what I needed to learn. But, instead, I simply made an

estimate of what I thought was happening. These estimates were as follows: the disk looked like it was spinning at the rate of 20 revolutions per second; it looked like there were around 16 small dots in a quarter revolution when the LEDs were flashing quickly; and the patterns changed once each second.

Based on these estimates, I decided to use a tick-based timing system. Something happens

**Figure 1.** Hand-held electronic toy that creates many different optical patterns on five colored LEDs as they spin around.





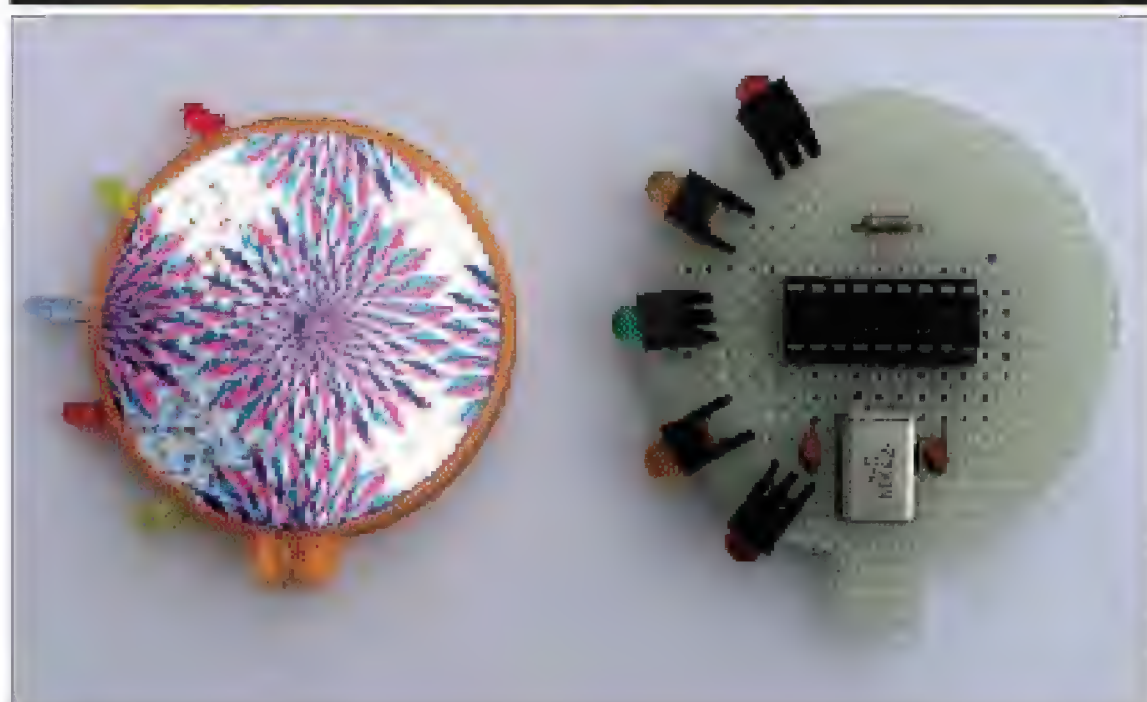
to each of the LEDs each tick. They either stay on or off, or change state. One revolution of the disk is equivalent to 128 ticks (a maximum of 16 on ticks and 16 off ticks per quarter revolution becomes 128 ticks overall). Using a random method, an LED is chosen to be on continuously, or to flash. The rate of flashing is controlled by two additional random numbers, one for off-period ticks and the second for on-period ticks. For example, the numbers 7 and 12 would indicate 7 off ticks and 12 on ticks. Arrays are used to keep track of the tick counts, state, and pattern type for each of the five LEDs.

While testing the software, I flashed a new program into the PIC and plugged the PIC into the development board. Then, by simply wiggling the board back and forth, I was able to see the LEDs flashing at different rates, or staying on, with new patterns emerging regularly. Listing 1 shows the PIC-BASIC program that controls the LEDs.

When the software seemed to be working, I spent a few hours building the prototype of the disk. In Figure 2 you can see the results of my attempt to duplicate the spinning disk. For balance, I placed the PIC microcontroller and crystal in the middle of the axis of rotation. Unfortunately, I did not notice the difference in LED colors until after I had soldered them to the circuit, but as this was a prototype, I didn't beat myself up over it. Figure 3 shows the schematic of the prototype.

All that remains is for me to mount the new prototype disk in the old toy housing and see how long it takes my daughter to figure out her toy had undergone an operation. Even if I still end up in the doghouse, at least now I know how to program a PIC. **NV**

**Figure 2.** The original spinning disk rests side-by-side with the new PIC16F628-based prototype.



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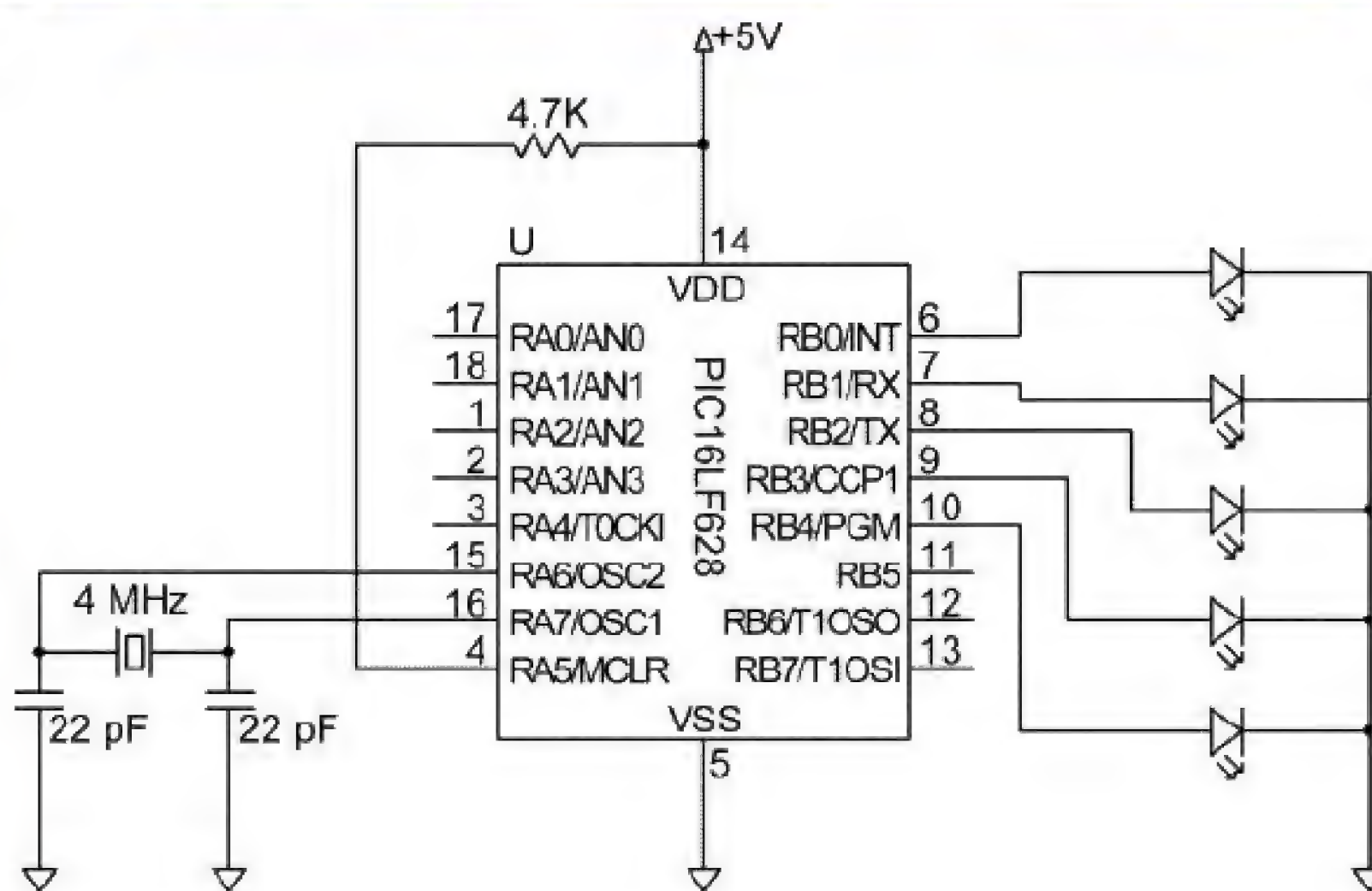
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## About the Author

James Antonakos is a Professor in the Departments of Electrical Engineering Technology and Computer Studies at Broome Community College, with over 29 years of experience designing digital and analog circuitry and developing software. He is also the author of numerous textbooks on microprocessors, programming, and microcomputer systems. You may reach him at [antonakos\\_j@sunybroome.edu](mailto:antonakos_j@sunybroome.edu) or visit his website at [www.sunybroome.edu/~antonakos\\_j](http://www.sunybroome.edu/~antonakos_j)

**Figure 3.** The PIC microcontroller offers a minimal part-count solution to the prototype design. Five I/O pins are used to control the LEDs.





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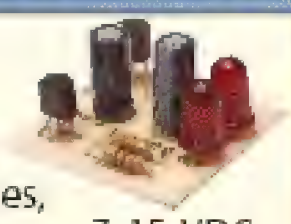
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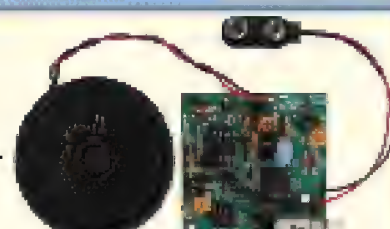
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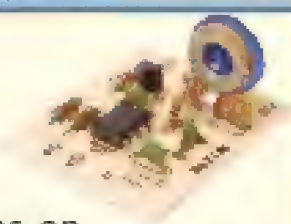
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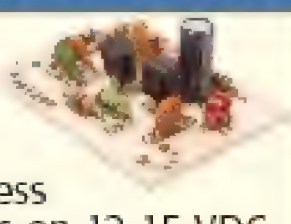
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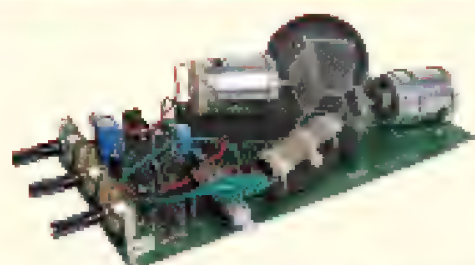
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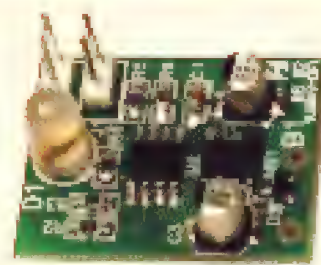


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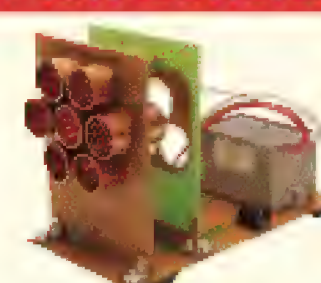


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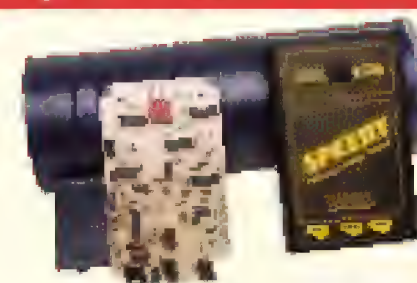


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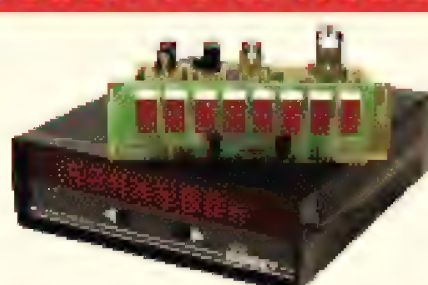


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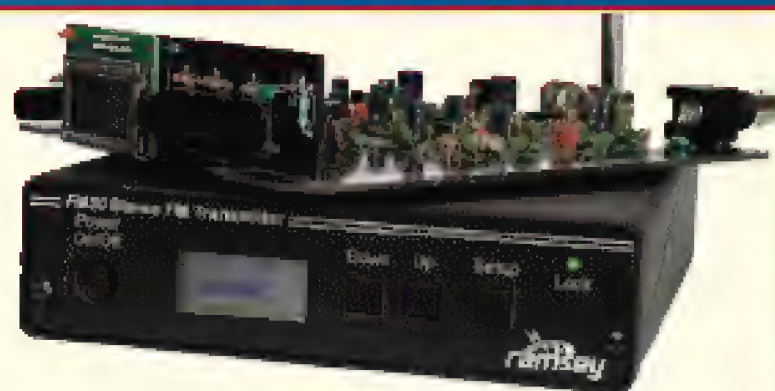


# FM Broadcasters

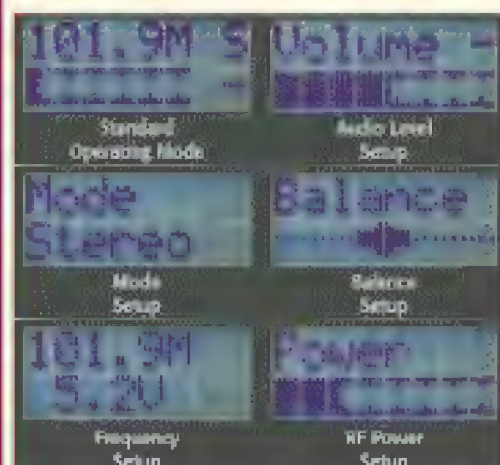
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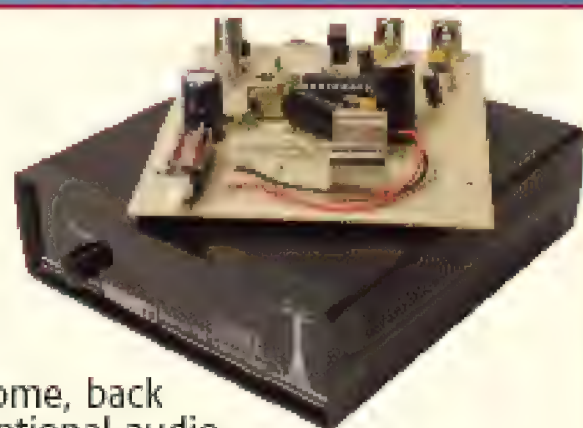
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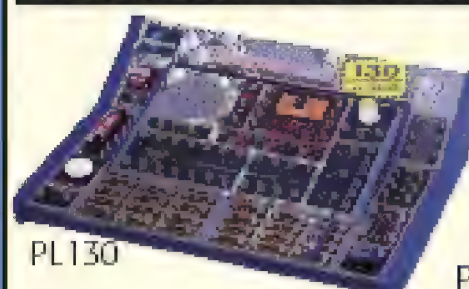
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## **CS ONLINE VERSION 2.2.0**

**C**onklin Systems announces the release of CS ONLINE 2.2.0, a VT102/ANSI/Telnet emulator with extensive data logging and serial debugging features ideal for industrial and engineering applications.

CS Online release 2.2.0 is, in a word, all about "color." 2.2.0 now supports ANSI color terminal emulation, making full use of color from Lynx, Vim, Emacs and other popular applications. CS Online now logs and highlights Input vs. Output data, making diagnosing serial data easier and approaching the capabilities of entry-level serial analyzers.

CS Online's new HTML logging mode is a breakthrough in data recording and analysis. With CS Online, you can now capture data directly on your Palm-powered device to a storage card in HTML format, fully highlighted and viewable both with an on-device browser and on the desktop. CS Online takes serial/bluetooth/IR emulation to the next level, with a product that cannot only connect to nearly all serial devices, but can diagnose problems with them, as well.

Conklin Systems acquired the popular Mark/Space product Online in 2005. Brian Hall, president and CEO of Mark/Space, Inc., notes, "With the 2.2.0 release, the first to add major new functionality since the transition, Conklin Systems has shown that Online is indeed in capable hands. The addition of new features both long needed in Online, and not available in any other comparable Palm OS software, shows both the commitment and capability of Conklin Systems."

For more information, contact:

## **CONKLIN SYSTEMS**

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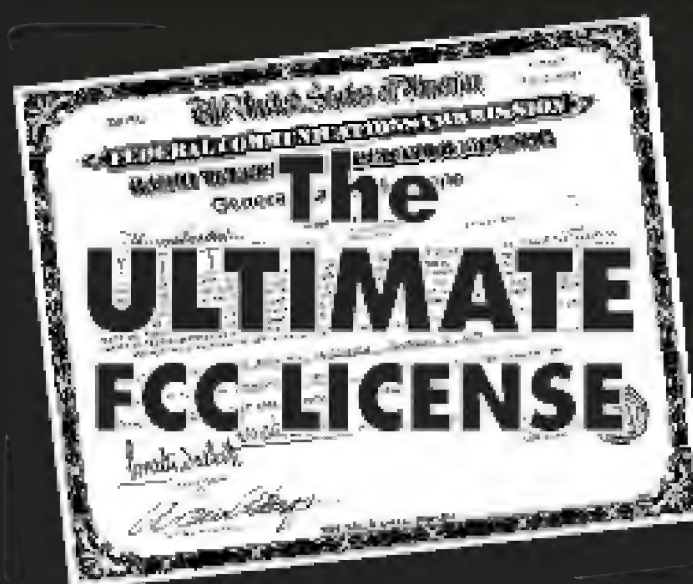
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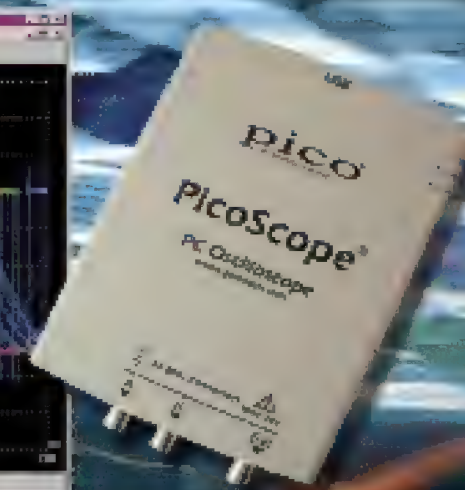
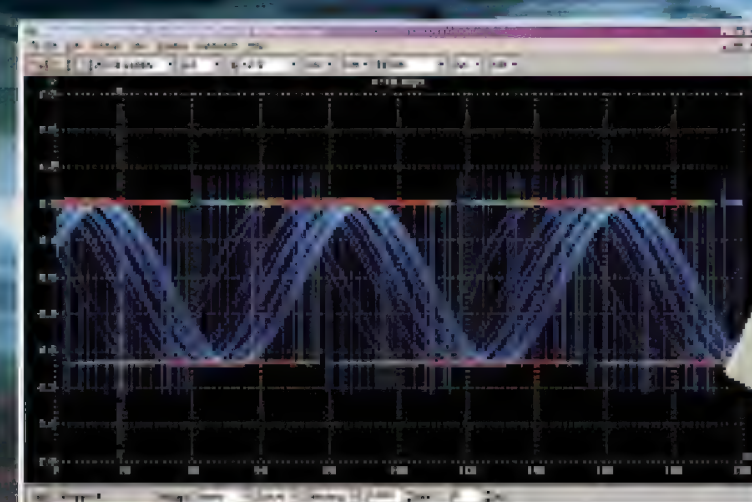
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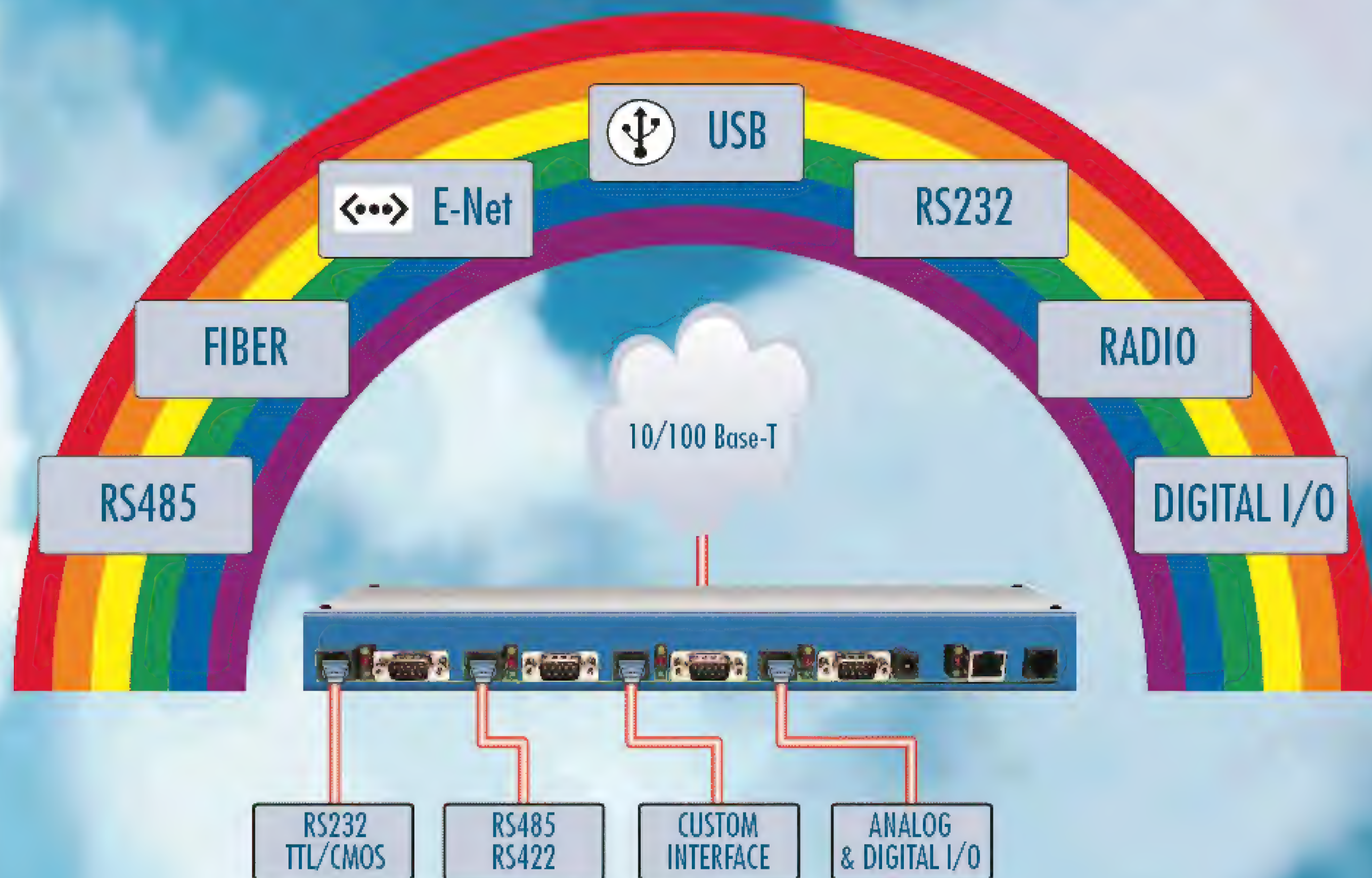
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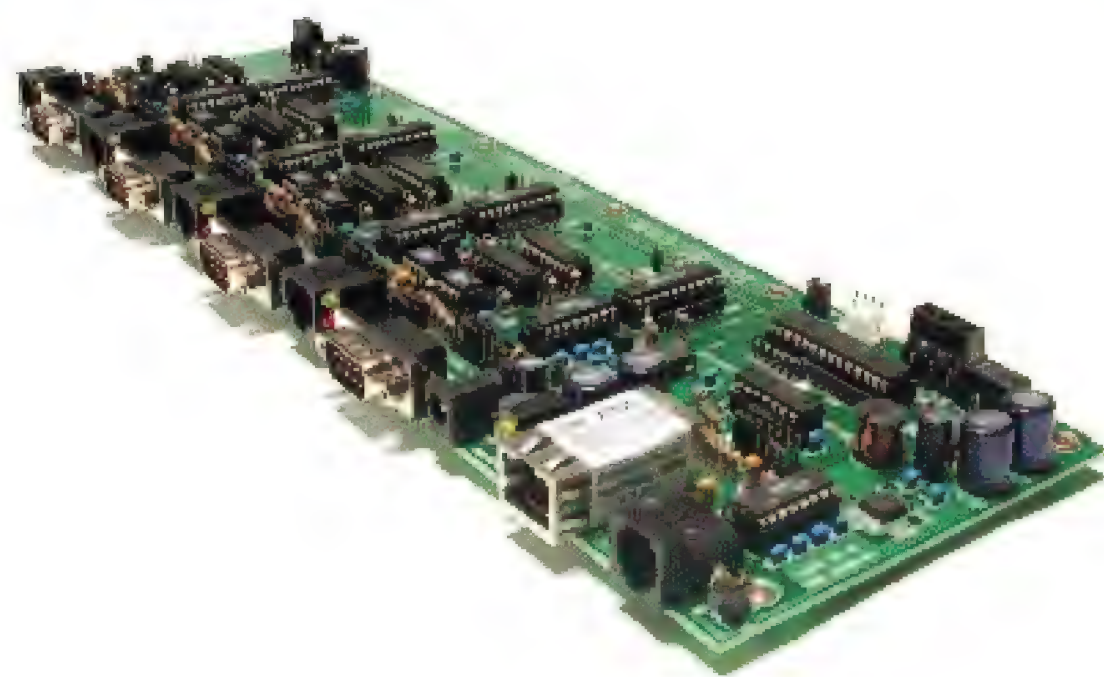


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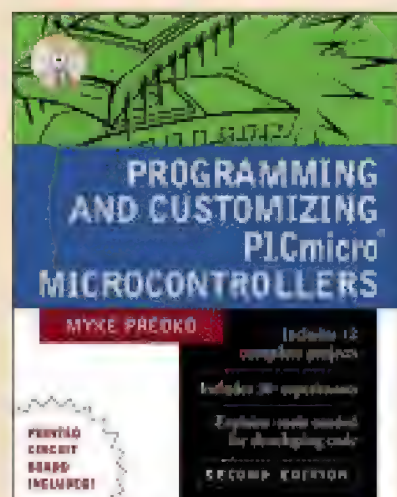
# The Nuts & Volts Hobbyist Bookstore

## Microcontrollers

### Programming & Customizing PICMicro Microcontrollers

by Myke Predko

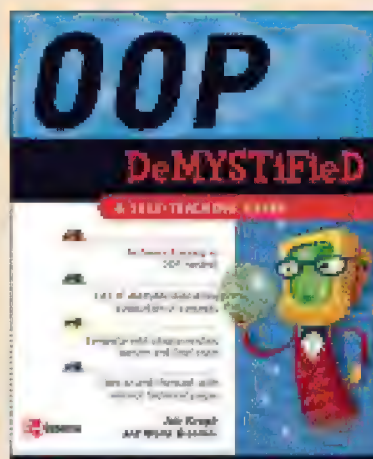
This book is a fully updated and revised compendium of PIC programming information. Comprehensive coverage of the PICMicros' hardware architecture and software schemes will complement the host of experiments and projects making this a true "learn as you go" tutorial. New sections on basic electronics and basic programming have been added for less sophisticated users, along with 10 new projects and 20 new experiments. The CD-ROM contains all source code presented in the book, software tools designed by Microchip and third party vendors for applications, and the complete data sheets for the PIC family in PDF format. **\$49.95**



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## Robotics

### The Official Robosapien Hacker's Guide

by Dave Prochnow

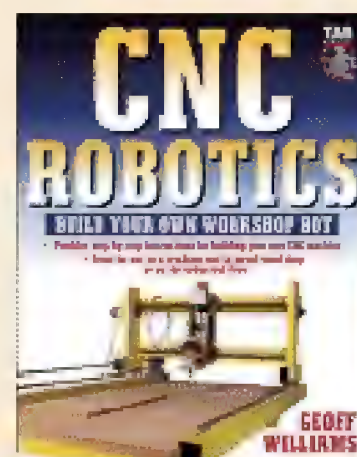
The Robosapien robot was one of the most popular hobbyist gifts of the 2004 holiday season. The brief manual accompanying the robot covered only basic movements and maneuvers — the robot's real power and potential remain undiscovered by most owners — until now! This is the official Robosapien guide — endorsed by WowWee (the manufacturer) and Mark Tilden (the designer). This timely book covers all the possible design additions, programming possibilities, and "hacks" not found anywhere else. **\$24.95**



## CNC Robotics

by Geoff Williams

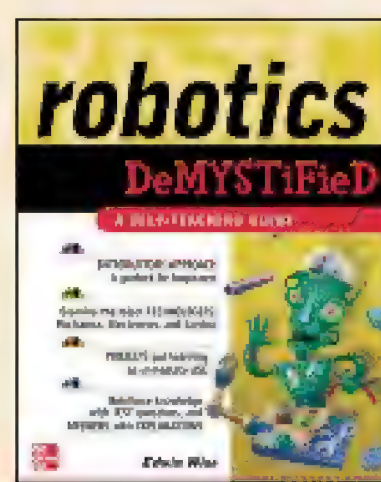
Written by an accomplished workshop bot designer/builder, *CNC Robotics* gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80% of the price of an off-the-shelf bot — and can be customized to suit your purposes exactly because you designed it. **\$34.95**



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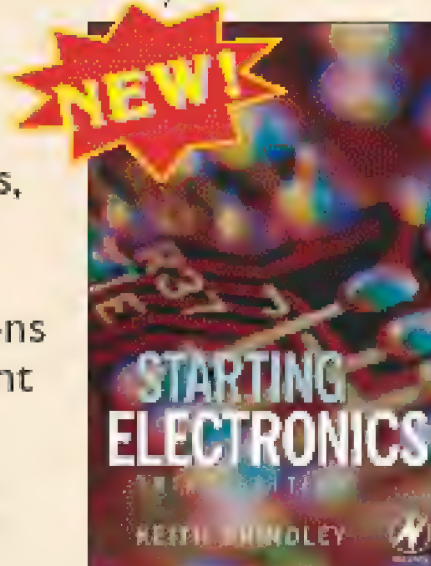


## Electronics

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by Keith Brindley

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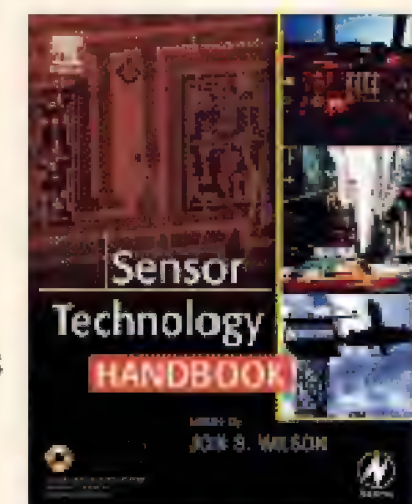
*Practical Optics* bridges the gap between what students learn in optical engineering curriculum and the problems they realistically will face as optical engineering practitioners, in a variety of high-tech industries. A broad range of topics from modern optical engineering are addressed, ranging from geometrical optics and basic layout of electro-optical instruments, to the theory of imaging, radiation sources and radiation sensors, spectroscopy, and color vision and description of optical methods for measurements of numerous physical parameters (temperature, flow velocity, distances, roughness of surfaces, etc.). **\$69.95**



## Sensor Technology Handbook

by Jon Wilson

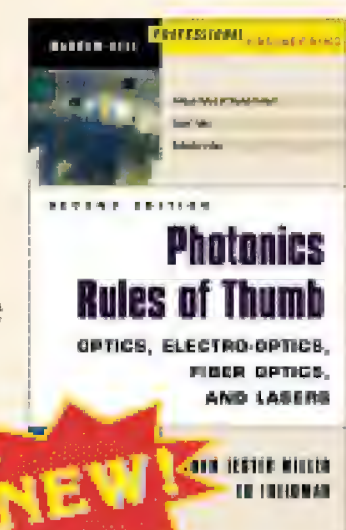
Without sensors, most electronic applications would not exist. The importance of sensors, however, contrasts with the limited information available on them. This volume is an up-to-date and comprehensive sensor reference guide to be used by engineers and scientists in industry, research, and academia to help with their sensor selection and system design. It is filled with hard-to-find information, contributed by noted engineers and companies working in the field today. The *Sensor Technology Handbook* will offer guidance on selecting, specifying, and using the optimum sensor for any given application. The editor-in-chief, Jon Wilson, has years of experience in the sensor industry and leads workshops and seminars on sensor-related topics. **\$99.95**



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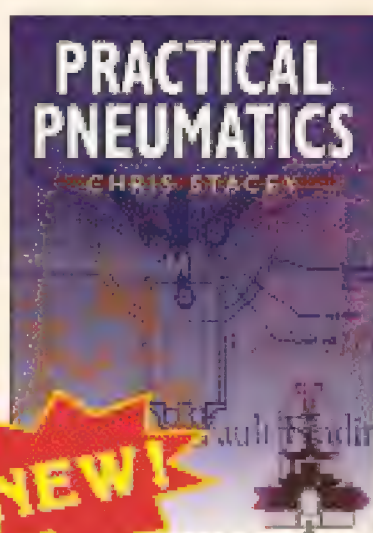


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## Practical Pneumatics

by Chris Stacey

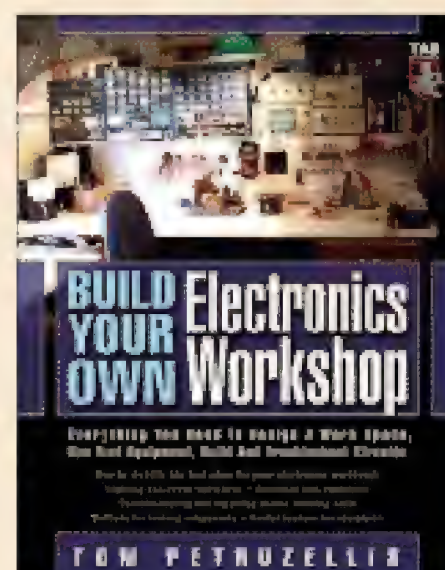
Pneumatic power is ideal for the ever increasing range of 'light' applications in which a cheap, clean, adaptable source of power is needed. Training courses and books aimed at the technician have not kept pace with these developments. *Practical Pneumatics* is written to cover the British Fluid Power Association Pneumatics Certificate, which is also awarded as part of CGLI scheme 2340, and is in the process of NVQ accreditation at level 3. This book provides a clear and detailed discussion of pneumatic technology by tackling the principles of pneumatic components and the behavior of air under compression, during treatment, and in applications to production processes. The non-mathematical approach, the numerous detailed diagrams, and the many exercises and examples explain concepts clearly and concisely, and provide students with a foundation from which to develop practical competence. **\$41.95**



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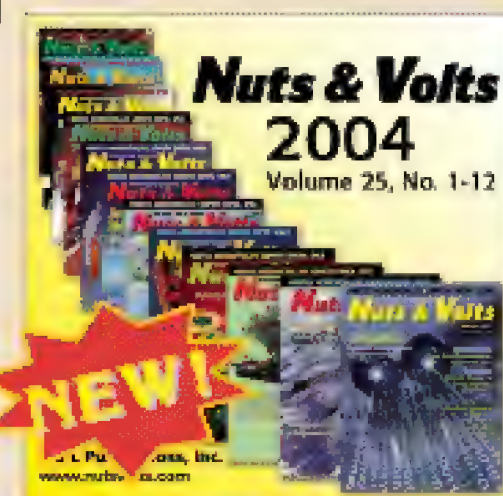
by Thomas Petruzzellis

*The Electronics Workbench* was created to assist the newcomer in the field of practical electronics through the creation of a personal electronics workbench. It is a place specially designed so that readers can go there to work on an electronic project, such as testing components, troubleshooting a device, or building a new project. The book includes invaluable information, such as whether to buy or build test equipment, how to solder, how to make circuit boards, how to begin to troubleshoot, how to test components and systems, and how to build your own test equipment, complete with appendix & resources, etc. This is *THE* book for anyone entering the field or hobby of electronics. **\$29.95**



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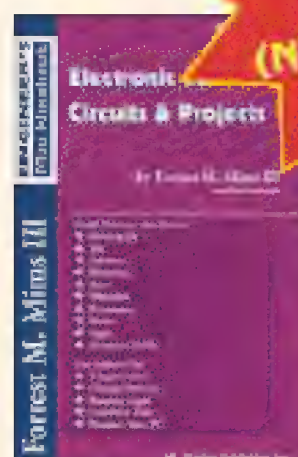


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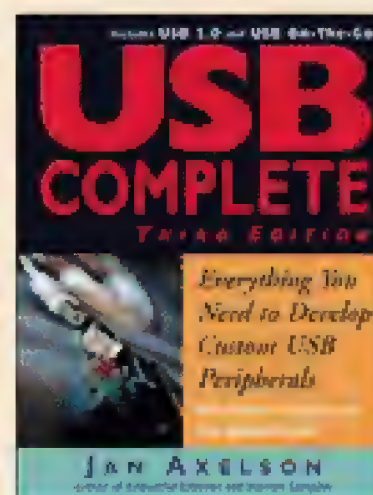
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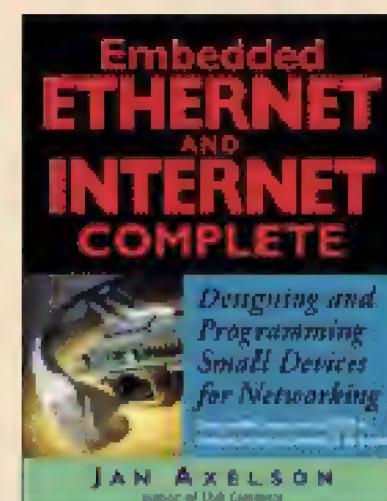
This completely revised edition of *Introduction to Computers* offers a comprehensive grounding in computer concepts, reflecting on some of the latest advances in technology, to prepare students for the next level of computer productivity. It includes three entirely new chapters on the Internet, computer graphics, and multimedia. **\$58.75**



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# Pool Timer

## Build Your Own Pool Timer and Let it Do the "Dirty" Work!

### This Month's Projects

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Instant Replay .....	42



### The Fuzzball Rating System

To find out the level of difficulty for each of these projects, turn to Fuzzball for the answers.

The scale is from 1-4, with four Fuzzballs being the more difficult or advanced projects. Just look for the Fuzzballs in the opening header.

You'll also find information included in each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!

About a year ago, when I created a floating pool light and shared it with readers, I received a number of positive responses. Around the same time, I also developed a pool timer. I've since refined the project and developed a new prototype, which I've outlined here.

Shown in Figure 1, the first timer had a clock-like interface and various buttons for controls. You set each hour you wanted the pump to turn on. The yellow LED in the middle was the AM/PM indicator, so you had 24-hour control over the pump.

Although the timer worked, it was a bit too complicated for anyone else in the family to use. I promised my wife that, next year, I would build a simpler timer.

As I used both this timer and others, the one thing that surfaced was that turning on the pump was more a factor of duty cycle than actual time of day. For instance, I found that, if the pool needed extra cleaning because of a storm or heavy use, I would set the timer for "ON 2 hours and OFF 1 hour." Once the pool was cleaned to my satisfaction, I would drop the timer back to "ON 1 hour

and OFF 2 hours." What I really needed was a timer control that would let me set a long-term duty cycle for the pump over a three- or four-hour period.

Let's take a look at a few requirements for the new timer.

- Ability to control duty cycle
- Simple control system
- Self-contained (No AC adapters)
- Ability to override the timer
- Ability to reset the timer

My first prototype used two knobs. One knob was used to control the on-time, while the second knob was used to control the off-time. While this worked, it required fiddling with two knobs to override the timer. I also felt that I could make the interface simpler.

Eventually, I ended up with a single-knob control system. The only indicator was a red LED to denote the status of the control relay. The actual position of the knob gave the only feedback needed to control the timers.

### The Control

Figure 1. The old pool timer.



Figure 2. Duty cycle positions.



Because the knob is the only control, the timer is very easy to set. By placing the knob indicator in the middle position, the pump is on two hours and off two hours. By moving the knob in either direction, I could change the amount of on- and off-time in proportion to the position of the knob.

Figure 2 shows how the various positions affect the duty cycle. Placing the knob all the way to one side or the other let me override the timers



completely. In this way, I can turn the timer off or on at will.

Note that the timer is based on a four-hour cycle. This can be changed in the program code to whatever you wish. Later, I will explain in more detail how to do this.

## Construction

Let's take a look at the circuit. Having only one control keeps the number of parts to a minimum. Most of the components are actually used in the power system.

In order to keep the construction details simple, I will look at each sub-system individually. You can make your own decisions based on the components you have in your junk box.

## Power System

Schematic 1 shows the power system. I used a very small low-power 300 mA transformer to supply both the power to the microcontroller circuit and to the controller relay. It's important that you use a 12 volt transformer so that you can power the controller relay from a tap off the rectifier bridge. If the relay you decide to use draws more than 250 mA, you will need to use a larger transformer.

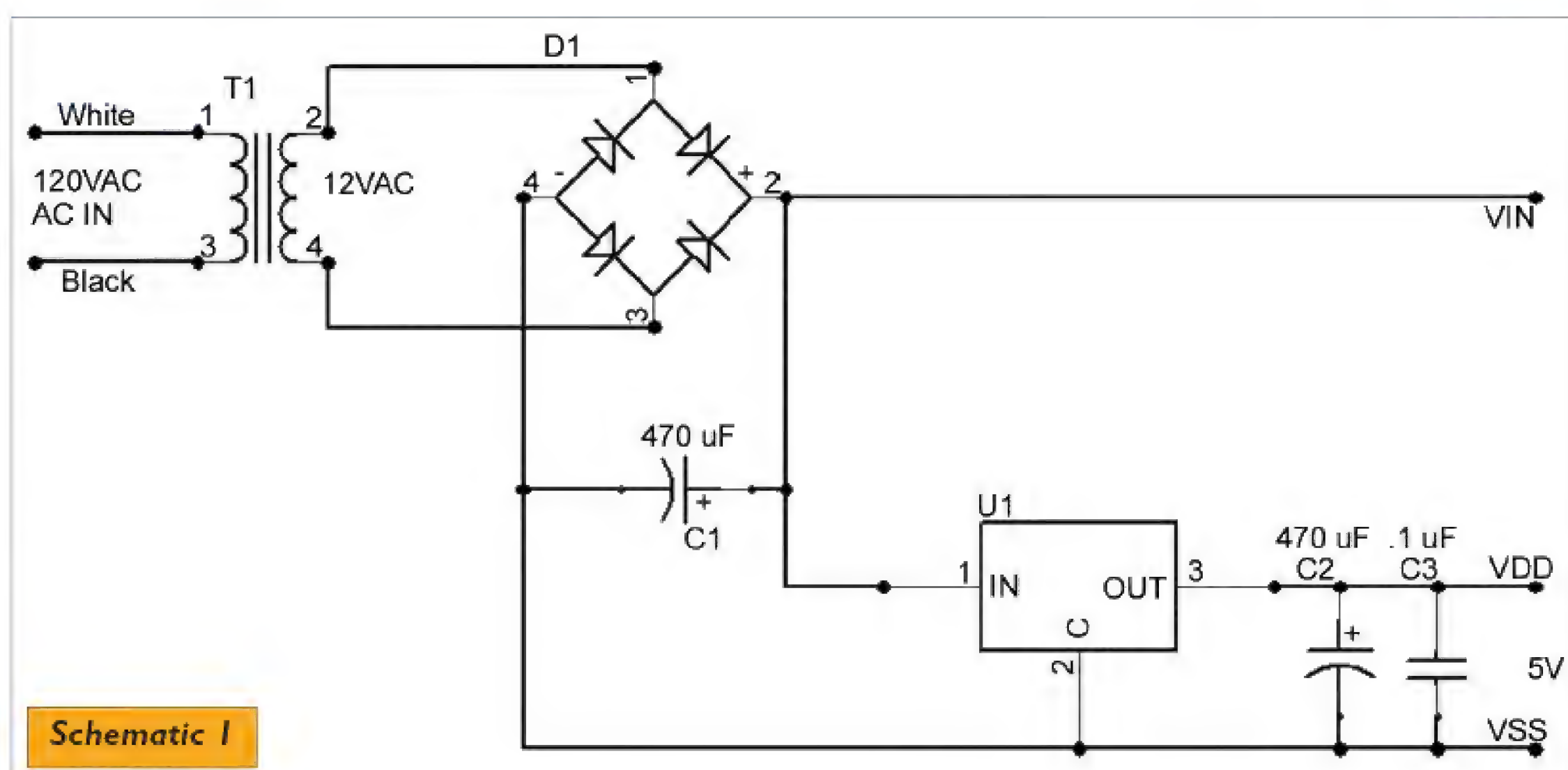
U1 is a simple 1 amp 7805 regulator. You can use just about any 5 volt regulator to power the logic circuit. The two 470 uF capacitors are very important; if you have larger capacitors in your junk box, you can use those.

## Logic System

I used the Nemesis microcontroller because it's small, cheap, and you don't need an expensive programmer to program it. The Nemesis has seven A-to-D ports that I used to read the position of the knob, and plenty of ports for driving the indicator and control system. Other than that, I only needed a single .1 uF and 10K resistor for support components.

Schematic 2 shows how I connected R2, the control knob. Any potentiometer from 1K to 100K can be used. Just make sure it is not an audio taper.

In order to program the Nemesis, I also needed a RS232 interface. You can build one with a MAX232 chip or purchase one for less than \$10 from the Kronos Robotics website ([www.kronosrobotics.com](http://www.kronosrobotics.com)). The software for programming the Nemesis is free and can also be downloaded from the website.



Schematic 1

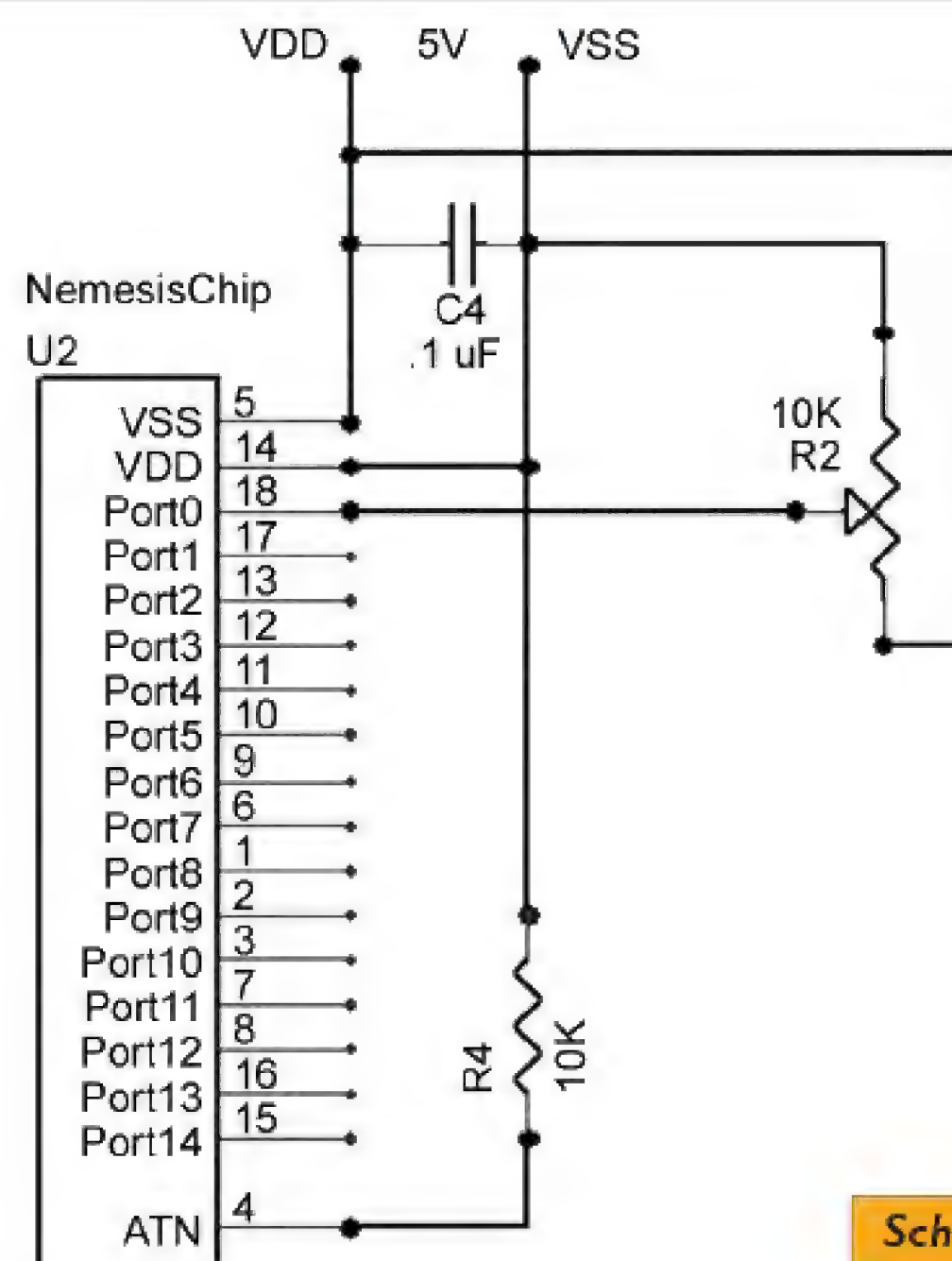
## Indicator System

Other than the knob itself, I only needed a single LED to display the state of the control relay.

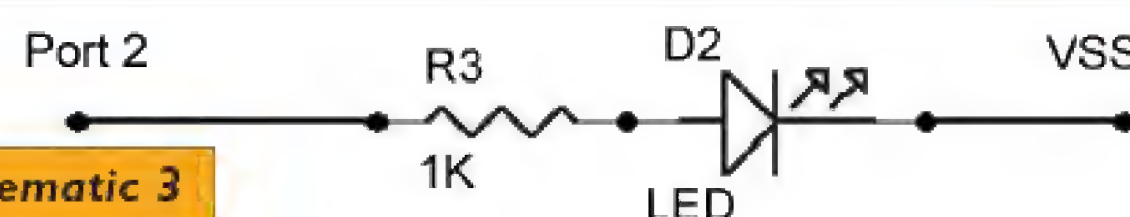
Any LED will work. I also needed a resistor, used to drop the 5 volt regulator, down to an acceptable level, as shown in Schematic 3.

## Control System

The control system consists of a TIP 41 Darlington

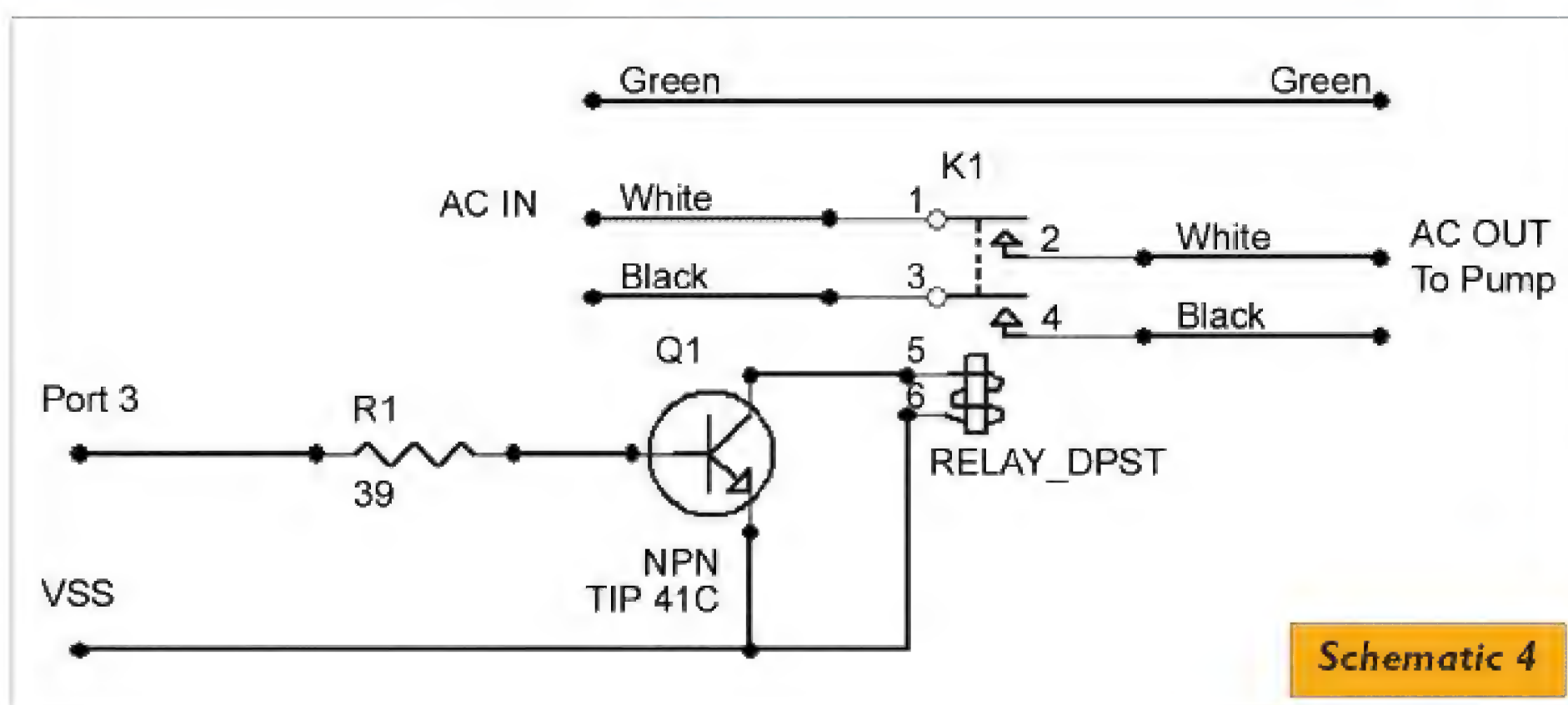


Schematic 2



Schematic 3





power lead. If your pump is 220 volts, I really recommend a DPDT relay so you can switch both sides of the circuit.

When I build circuits such as these, I like to purchase a 50' or 100' extension cord and cut it down to a couple of feet. This gives me a nice male and female connector, as well as any length of cord I may need. Buying the longer cord also tends to be cheaper than purchasing the special plugs needed. If you are running 220 volts, you may just need to hardwire the circuit anyway.

transistor and a DPDT 12 volt relay.

I like using the TIP 41 in situations like this, as it has a bypass diode built in to keep the relay from destroying the transistor when the field collapses.

The relay can be any 12 volt DC relay, as long as the contacts can handle the pump you are controlling. I am currently using a 12 volt relay with 20 amp contacts. Originally, I used a 30 amp 12 volt automotive relay. These relays will work, but will draw a bit more current than your typical DPDT 12 volt relays. If you do decide to use an automotive relay, make sure you switch the black (or hot)

## PCB

Kronos Robotics has several PCBs for the various microcontrollers. The Athena WorkBoard PCB is perfect for this project. It has provisions for connecting the AC with the rectifier and regulator on board. As there are provisions for an RS232 driver, you can also use the board to program the chip. There is also a very generous prototyping area on the PCB for adding the potentiometer, indicator, and transistor.

Note that the PCB is also available in a Carrier board configuration, which makes it extremely easy to proto-

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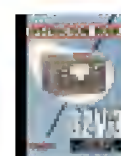


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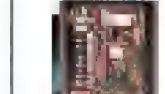
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type your circuit.

## Case

I purchased an Industrial Control Enclosure from All Electronics to house my project; unfortunately, these are no longer available. I recommend that you first choose your PCB and other components. You can then determine the size of the case needed to enclose your circuit, transformer, and control relay.

My pool shed tends to leak, so I wanted to make sure the case was waterproof. I sealed all holes with hot glue and made sure all cables exited at the bottom or underside of the case.

## Software

In order for the Nemesis to do its job, I needed to load it with a small program. I say small because this program only uses about one-twentieth of the available memory. (Go to the *Nuts & Volts* website for the program code; [www.nutsvolts.com](http://www.nutsvolts.com))

The knob is read once each second and its values are checked against internal timers. In order to get the length of time needed, I used two counters, the littlecounter and maincounter. Think of the littlecounter as an inner counter. It is incremented once each second, and, when it reaches 60, the maincounter is incremented.

By doing this, the maincounter represents minutes. You can shorten or lengthen this interval by changing

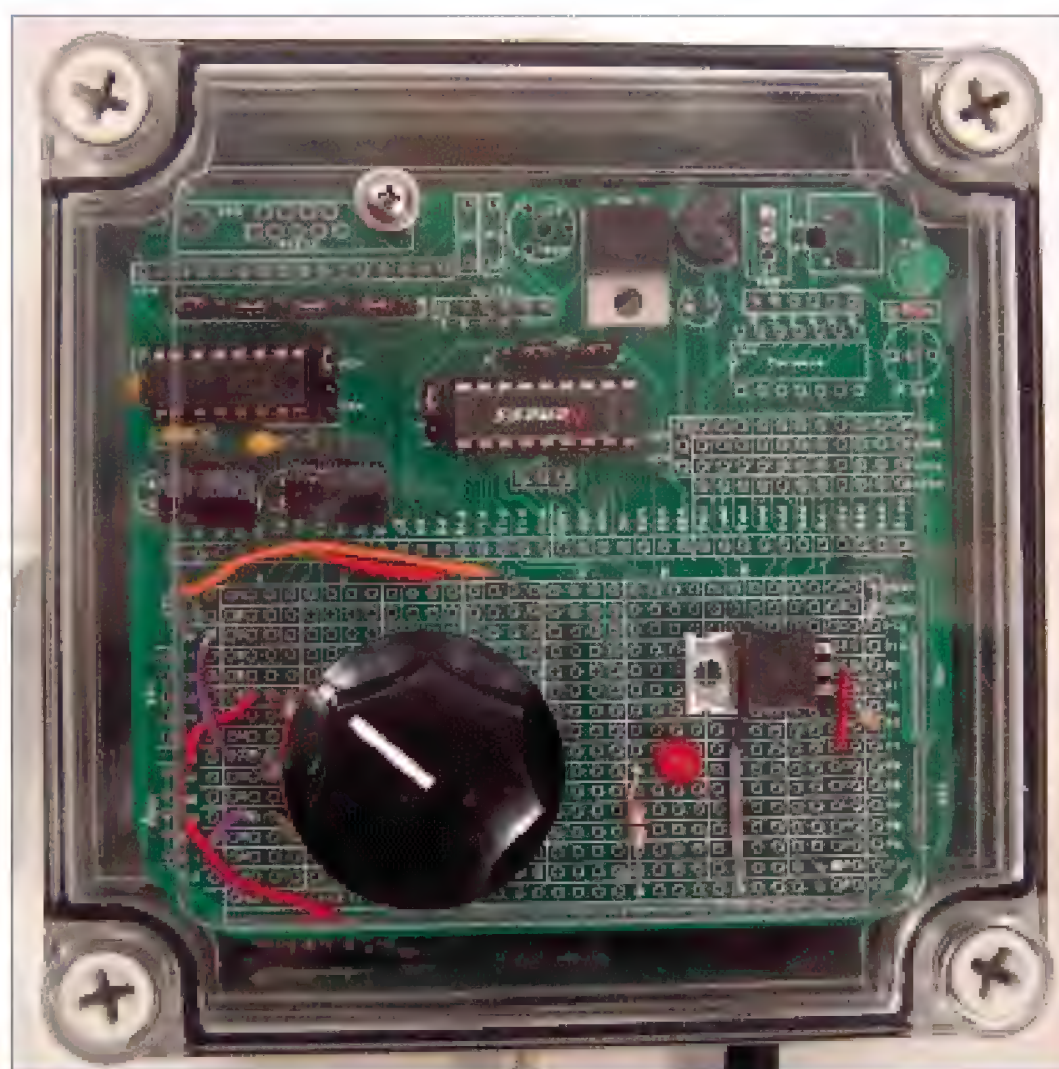


Figure 3. The new pool timer.

the littlecounter threshold.

## Final Thoughts

I'd like to conclude with a word about safety. If you decide to build this circuit, I can't place enough emphasis on how important it is to use a CFGI outlet. If you are not currently using a CFGI outlet, then I recommend you install one.

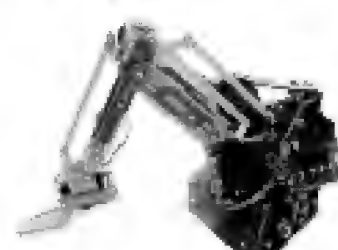
The Nemesis is a very powerful microcontroller and supports a high level basic language as well as inline assembly. I haven't even touched on the kinds of enhancements you could add to this timer. The Nemesis also has a command for controlling a TW523 X10 transceiver. By utilizing this device, you could use an appliance module to control the pump. Be sure to visit the Kronos Robotics website for updates to this and other articles. **NV**

## Parts List

Qty	Description	Source and Part Number
1	Nemesys Microcontroller	Kronos Robotics #16406
1	Athena WorkBoard PCB	Kronos Robotics #16460
1	Athena WorkBoard Deluxe	Kronos Robotics #16457
1	EZ232 driver	Kronos Robotics #16167
1	7805 5 volt regulator	Kronos Robotics #16208
1	Bridge rectifier	Kronos Robotics #16136
1	Potentiometer	See Text
1	Transformer	RadioShack #273-1385B
1	Relay	See Text
1	TIP41	Jameco #33081
1	Athena Compiler Software	Free download from Kronos Robotics website.

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Wireless Door Alarm **\$12.95**  
Sound Activated Recorder **\$9.95**  
AM/FM Radio **\$14.95**  
Digital Multimeter **\$18.95**  
Robotic Arm Control **\$295**

### Dip Meter



**DM-4061A \$89.95**  
(1.5~250 MHz)  
Modulation: 2KHz sinewave  
Crystal Oscillator: 1~15 MHz

### Oscilloscopes



**OS-45010 (10MHz) \$159.95**  
**OS-45020 (20MHz) \$245**  
**OS-22250 (25MHz) \$315**  
**OS-45040 (40MHz) \$395**  
**OS-22400 (40MHz) \$469.95**  
**OS-22600 (60MHz) \$679**  
**OS-221000 (100MHz) \$849.95**

### Oscilloscope Probes



**HP-9060 (60MHz) \$15**  
**HP-9100 (100 MHz) \$20**  
**HP-2100 (100 MHz) \$20**  
**HP-9258 (250MHz) \$39**

### Audio Generators



10Hz~1MHz, sine / square  
**AG-2601A \$125** analog display  
**AG-2603AD \$225** digital display  
with built-in 150MHz freq.counter

### Signal Generators



(100k~150M Hz in 6 ranges  
RF output: 100m Vrms)  
**SG-4160B \$125** (analog display)  
**SG-4162AD \$224.95** w/built-in  
150MHz freq. counter (digital display)

### Breadboards & Jumper Wires



**BB-27101 (740 contact pts) \$3.75**  
**BB-27102 (840 contact pts) \$4.45**  
**BB-271060 (2420 contact pts) \$17.25**  
Jumper Wires 140 pcs **\$3.75**  
Jumper Wires 350 pcs **\$8.25**

### Digital Multimeter



**DMM-1250 \$74.95**  
3 1/2 digits, Diode, hFE, Data Hold  
Frequency to 20 MHz  
Capatance to 20 µF  
Resistance 20 MOhm  
Temperature to 1999 F  
ACA/ DCA to 10 A  
DCV: 1000V, ACV: 750V  
Holster, and type K temperature probe included

### Soldering Stations



**SS-31998 (15~60W) \$27**  
**SS-31976 (50 W) \$37.50**  
**SS-31010 (48W) \$46**  
**SDS-31916 (solder/desoldering) \$295**  
\* replacement tips in stock

### IC Testers & EPROM Programmers



**DIC-17001 (Digital IC Tester) \$179.95**  
**LIC-17002 (Linear IC Tester) \$579.95**  
**EDP-17003 (EPROM Writer) \$249.95**  
**ERE-17121A (EPROM Eraser) \$74.95**  
**UDP-17010 (ROM Writer) \$575.00**

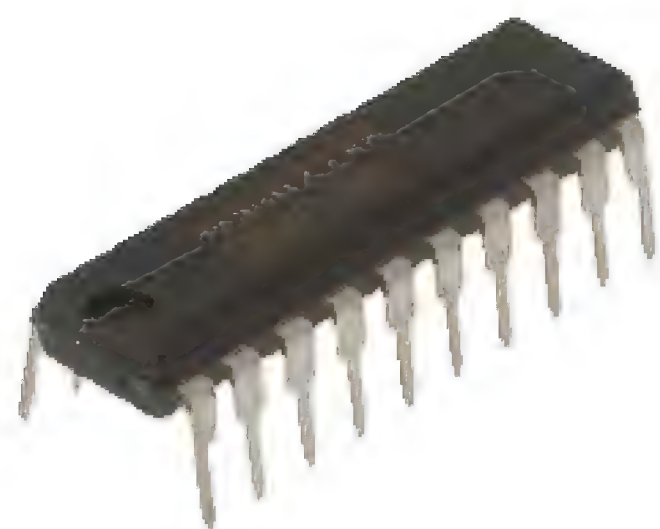
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# Build an RC Car on the Cheap

## Versatile Circuit Allows for Personal Customization

**R**adio control racing can be a fun and rewarding hobby. Over the years, I have designed numerous electronic projects, but this one was the most fun to build and use. While there are many advantages to building your own RC car or vehicle from scratch, the bottom line is that you can modify it to suit your needs. This multiple function car was built on the cheap with inexpensive electronic components and a body from a wire-controlled car that can be purchased from any toy store for about \$10.00. The wire-controlled cars are those with the joysticks connected to the cars by trailing wires. While you may only want to use this circuit to design RC cars, you can also use it in boats, planes, and robots, or even to open your garage door.

The car will go forward, stop, and reverse, and the steering is time proportional. With time proportional steering, the longer you hold down the joystick, the farther the wheels will turn left or right. This allows for precision in wide or tight turns.

### Circuit Description

When I designed this RC circuit, I didn't want it to have dual power supplies, or analog filters (high, low, or band pass). I wanted to keep the analog circuitry to a minimum. The circuit also needed to operate on a single frequency and have long range. I have seen too many radio controlled cars go off into the wild blue yonder after they lost communication with the transmitter. It also had to be inexpensive to build and have reasonable battery life.

### Transmitter

At first I didn't think I could meet all of these criteria, but with a little thought, things started to come together. After designing a couple of transmitters, I decided they either didn't have the range I needed or they were too bulky. So I opted to modify a commercial two-way radio. A two-way radio can be purchased for as little as \$10.00, is crystal controlled, and has good range. The first thing I needed to do was build a tone generator that could produce three frequencies in the audio range. Since most two-way radios have a limited audio frequency range — from about 500 Hz to 3,000 Hz — the frequencies chosen would be limited to this region. Figure 3 shows a block diagram of the transmitter and receiver.

Using a 4066 quad bilateral switch

and a couple of momentary switches, I was able to change the frequency of a 555 timer. The tone generator circuit is relatively simple: capacitors C1, C2, and C3 determine the frequency of the 555 timer. Since they are connected in parallel, disconnecting any capacitor from the circuit will change the frequency of the timer. If all three switches are open, the total capacitance seen by the 555 is .0127 uF, and a 751 Hz tone with an approximately 50% duty cycle is generated. The exact value of the tone generated may vary somewhat from these values due to the tolerances of the resistors and capacitors used. When SW1 is depressed, C1 is disconnected from the circuit and an 1,192 Hz tone is generated. If SW2 is depressed, C1 and C2 are disconnected from the circuit and a 2,029 Hz tone is generated. When SW3 is depressed, the timer is reset and no tone is generated.

The output of the 555 tone generator is connected to the electric microphone of the two-way communicator through a 10 uF capacitor and 100K resistor. If none of the switches are depressed, the two-way radio puts out a continuous tone of 751 Hz.

### Receiver

The tones are received at the other two-way radio, and the output from the speaker is connected to the tone decoder circuit through a 10 uF capacitor and a voltage divider consisting of 1K and 100 ohm resistors. From there, the signal transformed from an audio AC signal to a square wave DC signal by amplifying it through a LM324 Quad Operational Amplifier with a gain of 1,000. The square wave signal is measured by a relatively simple frequency counter consisting of a 4017 Decade Counter/Divider and one half of a 556 100 Hz oscillator. This part of the tone decoder is really the heart of the circuit. When a tone is received by the clock input of the 4017, it's counted until

Figure 1. View of remote control car.

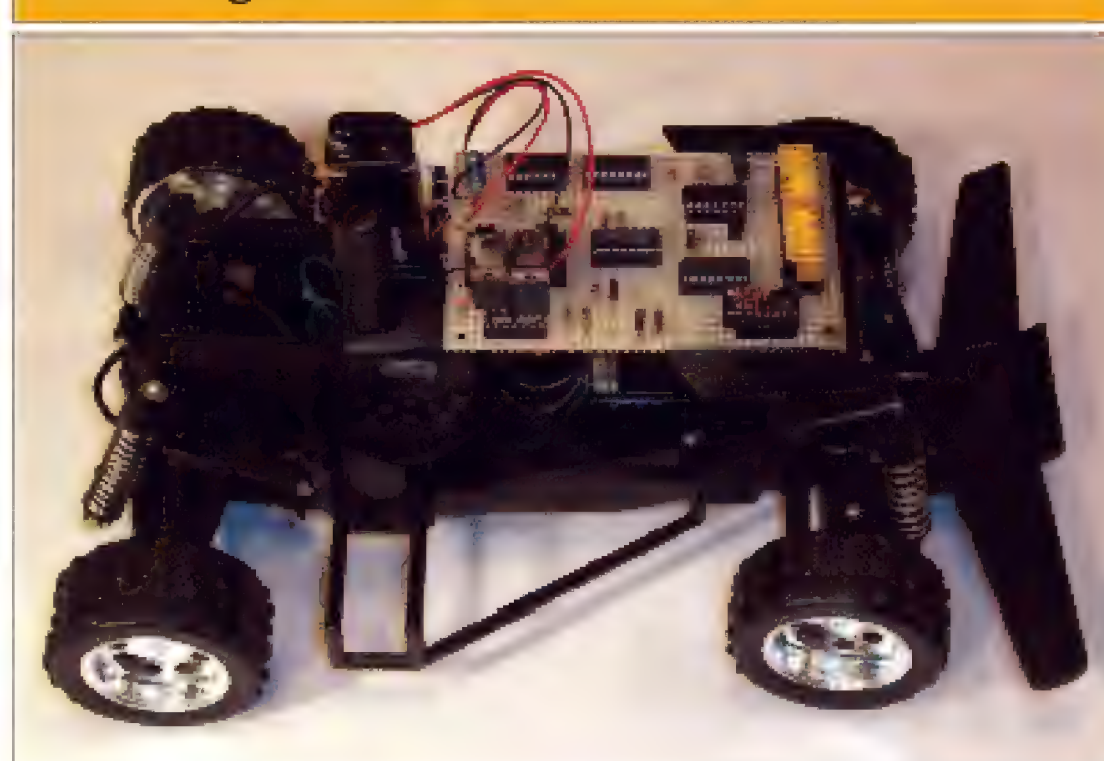
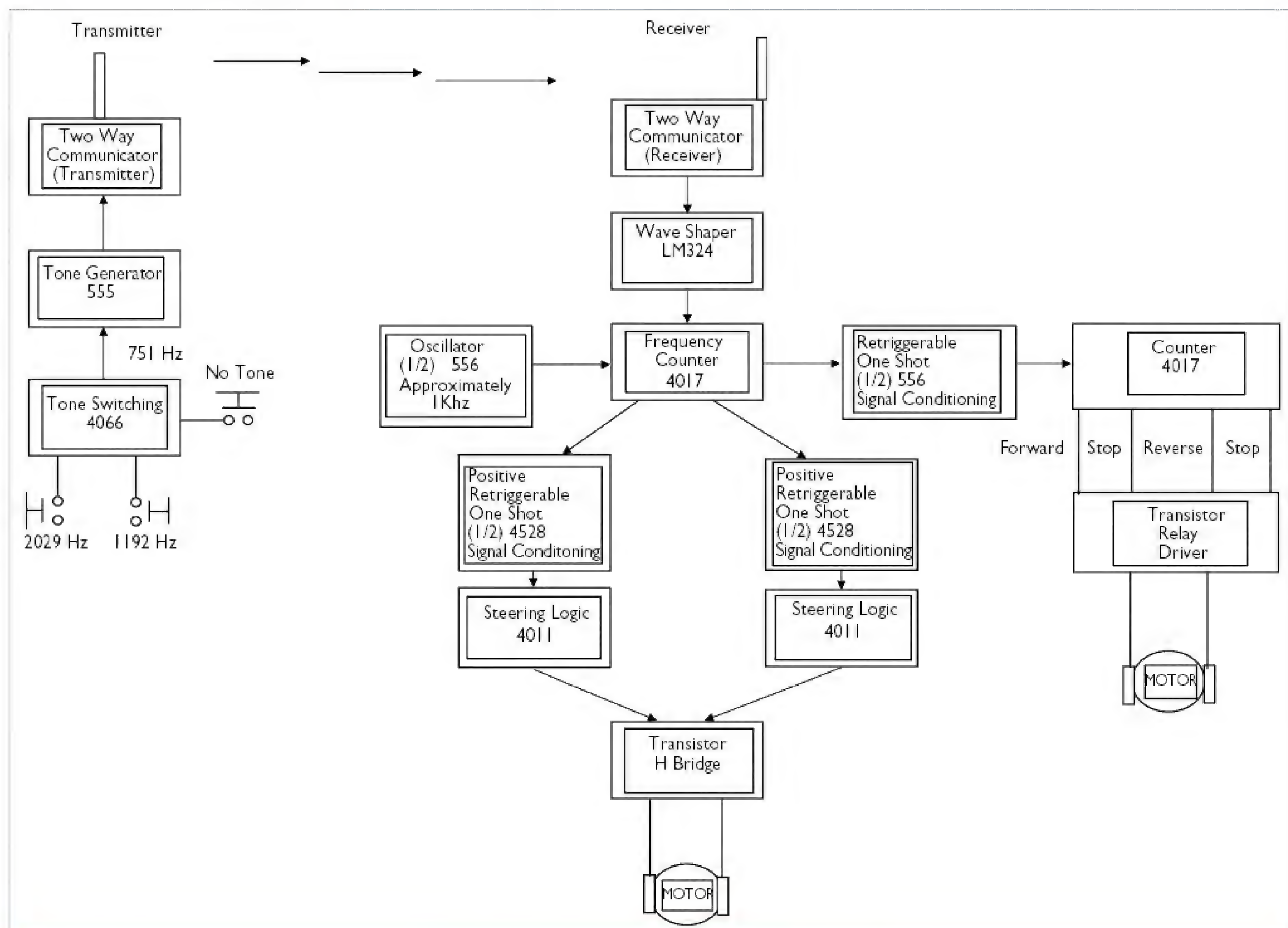


Figure 2. Transmitter for remote control car.







**Figure 3.** Block diagram of transmitter and receiver.

the positive half of the 100 Hz oscillator resets the circuit.

For example, if a 1,000 Hz signal is present at the clock input of the counter, only five pulses are counted. The counter then produces high outputs at pins 2, 4, 7, 1,

and 5 in rapid succession. Figure 4 shows a 100 Hz signal superimposed over a 1,000 Hz signal and should clarify the operation of the frequency counter.

Each output of the 4017 counter/divider will count fre-

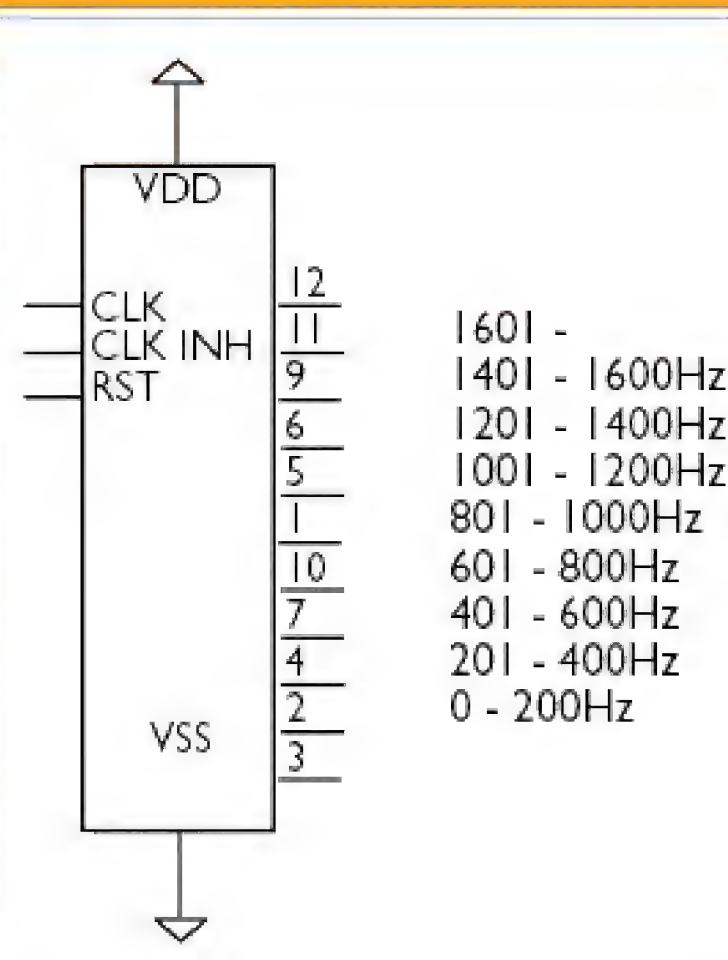
quencies in approximately 200 Hz increments. Figure 5 shows the output frequency for each pin. If you want to determine the exact frequency divisions for your circuit, measure the clock frequency and multiply by two.

Since the output from the 4017 is a square wave pulsating output, it must be conditioned before it can be used. The signal is sent to one half of the 4528 Positive Retriggerable One Shot — which conditions the output to a smooth continuous DC pulse. Values chosen for the One Shot were for a 0.1 second delay, but since it's retriggerable, the delay can be infinite if you have a continuous pulse train. From here, the signal is sent to the steering logic circuits, consisting of a 4011 NAND or 4070 Exclusive Or gate. If you look closely at the schematic, you will notice

**Figure 4.** Oscilloscope pattern of 100 Hz signal superimposed over 1,000 Hz signal.



**Figure 5.** The frequency output for each pin of the 4017.





that the 4011 NAND gate is configured as an AND gate.

The steering logic directs which half of the H-Bridge will be enabled. When the 2,029 Hz steering tone is transmitted, pins 2, 4, 7, 10, 1, 5, 6, 9, and 11 on the 4017 counter will go high, causing both halves of the 4528 to go high. This, in turn, causes the AND gate — consisting of two gates of the 4011 NAND to go high, turning on Q1 and Q4. Depending on how the motor is wired, it will turn either left or right. If the 1,192 Hz steering tone is transmitted, pins 2, 4, 7, 10, 1, and 5 on the 4017 will go high, causing only one half of the One Shot to go high. On the One Shot, pin 6 will be high while pin 10 will be low. This will cause the Exclusive Or to go high and turn on Q2 and Q3. The motor will now go in the reverse direction.

Forward, stop, and reverse are controlled by the 751 Hz tone. Since this tone is transmitted continually, absence of the tone changes the direction of the car. One pulse moves the car forward, two pulses stops it, three pulses reverses it, and four pulses stops the car again.

When pin 10 of the 4017 counter produces a low output, the inverter — consisting of 1/4 of a 4011 NAND gate — produces a high output, triggering the retriggerable One Shot which consists of transistor Q5 and 1/2 of timer LM556. As long as a continuous tone is sent, the output of the One Shot remains high, and no pulses are counted by the 4017 counter. When no tone is received, the One Shot goes low for .11 seconds and a pulse is counted by the counter. The two relays attached to the direction motor act as an H-Bridge. They were used instead of a transistor H-Bridge to extend battery life. Even though transistors have only a few ohms resistance when they are on, they draw considerable current when attached to a low-resistance device, such as a motor. In this case, good old fashioned relays work better than transistors.

At this point, you may ask why anyone in his right mind would transmit a continuous tone when a momentary tone would use less power. The rationale behind this was to solve a problem associated with two-way radios. Every time you press the transmit button on the communicator, it sends out a tone to alert the other party that you are calling, much like the ringer on a telephone. Since tone would be counted, it would act as a trigger tone, possibly activating the steering or direction of the car. To solve this problem, I decided to transmit a continuous tone. While this does waste some extra power, it doesn't amount to much because every few seconds you are sending steering or direction commands to your car anyway.

## Construction

The transmitter and receiver were constructed on perf-board. The ICs were mounted on IC sockets and soldered together using 30-gauge wire wrap wire. This produces a low profile circuit, which in many ways works as well as a printed circuit board. I used to wire wrap all my circuits, but found this mounting technique to be easier and faster. It's also less cumbersome when you need to modify or repair a circuit. All you have to do is desolder a connection and move the wires around.

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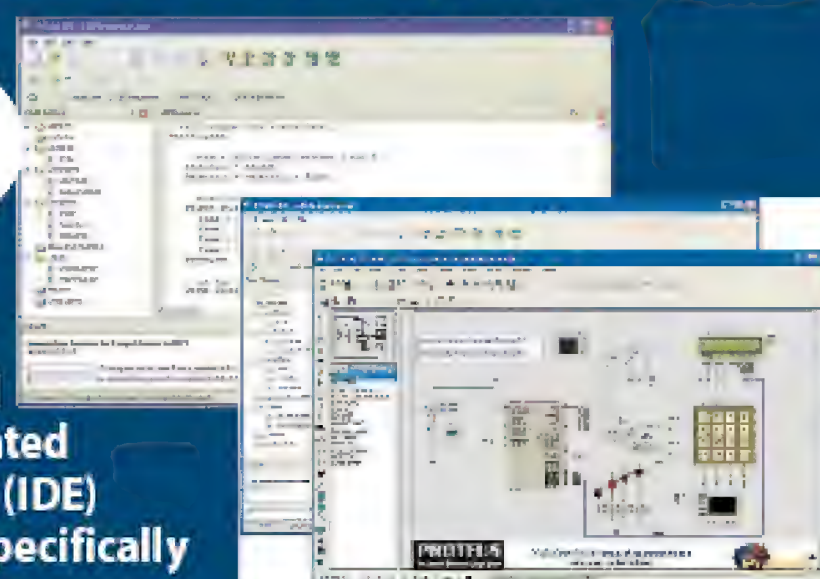
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## Project

I also used 30-gauge wire wrap wire to connect wires from the tone generator to the electric microphone on the two-way radio. To locate the connections for the microphone, you have to disassemble the receiver and trace the foil pattern. If a tone isn't transmitted when you push the transmit button, reverse the ground and input connections. Connection of the receiver to the speaker is much easier. All you have to do is locate the speaker and solder the ground and input leads to it.

## Testing

If your receiver doesn't work the first time, it's probably because component values are off. Ceramic capacitors

have this dubious distinction, and can be off as much as 20% from their stated value. I strongly suggest that you use good quality Mylar capacitors instead. If you are stubborn like me and you use ceramic capacitors, measure the values with a meter, and add capacitors in parallel to get the correct value. If you don't have a meter that can read capacitance, the problem is still easy to fix. Just change the placement of the wires on the 4017 frequency counter. For example, if you are having problems with steering, change pin 5 to either pin 1 or 10 or pin 11 to 9 or 6. If you are having problems with forward, stop, or reverse, change pin 10 to either 7 or 1.

If you really want to get your project to work the first time, I strongly suggest that you pretest circuits as you build them. It's rare not to make a few wiring errors the first time.

I always test circuits as I build them, and I usually get a project to work the first time. All you need is a couple of extra components, three resistors, and three LEDs. Every time you finish a circuit, attach the resistor and LED at the output of each IC. For example, to test the LM556 oscillator, connect the resistor and LED to pin 9. It should stay lit continuously. To test the 4017 counter, attach LEDs to pins 10, 5, and 11, and transmit the various tones to the counter. You will see the LEDs light for each tone. They may not be very bright due to pulsating output, so you may have to turn off the lights to see them. Next, connect an LED resistor combination to pins 6 and 10 of the 4528. When you transmit the steering tones, you will see LEDs go on. Since the signal is no longer pulsating, they will be very bright. Do the same thing for the other half of 556 One Shot pin 5. Then test the outputs of the other 4017 counter, pins 2, 7, and 10.

## Going Further

It bears repeating that the beauty of building your own radio control vehicle is that you can modify it to suit your needs. For example, if you need speed control you can add extra logic to the counter and inverter. The inverter could be made from either a 555 or a 4011. You could also install headlights, or, if you need more precise turning, slow the speed of the turning motor by adding a speed control unit. There are endless possibilities. **NV**

## Parts List

### Transmitter

U1 — CD4066 Quad Bilateral Switch  
 U2 — LM555 Timer  
 C1 — .0047  $\mu$ F Mylar Capacitor  
 C2 — .0033  $\mu$ F Mylar Capacitor  
 C3 — .0047  $\mu$ F Mylar Capacitor  
 C4 — 10  $\mu$ F 15V Electrolytic Capacitor  
 C5 — .1  $\mu$ F Capacitor  
 R1,R2,R6 — 100K, 5% Resistor  
 R3 — 10K, 5% Resistor  
 R4 — 68K, 5% Resistor  
 R5 — 15K, 5% Resistor  
 SW1, SW2, SW3 — Normally Open  
                     Momentary Switch  
 SW4 — Single Pole, Single Throw Switch

## Receiver:

U1 — LM324 Quad Operational Amplifier  
U2 — LM555 Dual Timer  
U3, U7 — CD4017 Decade Counter/Divider  
U4 — CD4528 Dual Monostable

### Multivibrator

U5 — CD4011 Quad Two Input NAND Gate  
U6 — CD4070 Quad Exclusive Or Gate  
Q1,Q2,Q3,Q4 — TIP 122 NPN Power Transistor or Equivalent  
Q5 — 2N3905 PNP Transistor or Equivalent  
Q6, Q7 2N2222 NPN Transistor or Equivalent  
C1 — 10 uF 15V Electrolytic Capacitor  
C2 — .1 uF Mylar Capacitor  
C3,C4,C5,C6 — .1 uF Capacitor  
R1,R10,R11,R12,R13,R15,R16 — 1K, 5% Resistor  
R2 — 100 ohm, 5% Resistor  
R3,R5 — 10K, 5% Resistor  
R4 — 10Meg, 5% Resistor  
R6 — 68K, 5% Resistor  
R7 — 15K, 5% Resistor  
R8,R9,R14 — 1 Meg, 5% Resistor  
D1,D2 — 1N914 Diode  
RLY1,RLY2 Six Volt Relay with .5 Amp Contact

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### Theremin Synthesiser Kit

KC-5295 \$34.95 + post & packing

The Theremin is a weird musical instrument that was invented early last century but is still used today. The Beach Boys' classic hit "Good Vibrations" featured a Theremin. By moving your hand between the antenna and metal plate, you create weird sound effects like in those scary movies!

Kit includes a machined, silk-screened, and pre drilled case, circuit board, all electronic components, and clear English instructions.

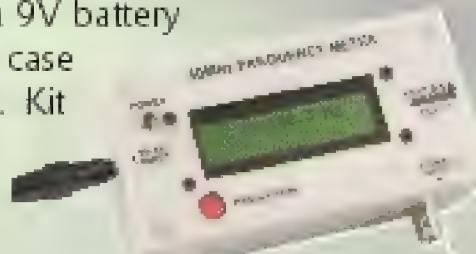
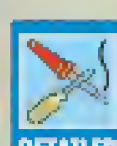
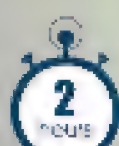


9VDC wall adaptor required (Jameco #252751 \$10.95).

### 50MHz Frequency Meter Kit with LCD Display

KC-5369 \$49.95 + post & packing

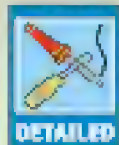
If you want a great value frequency meter, then this project is for you. It features autoranging operation for ease of use, switching between its three ranges. High resolution of 0.1Hz up to 150Hz, 1Hz between 150Hz and 16MHz, and 10Hz above 16MHz. It can be powered by a 9V battery or wall adaptor (not included) and the case measures just 5 1/8" x 2 5/8" x 1". Kit includes laser cut & silk screened case, circuit board, electronic components, & clear English instructions.



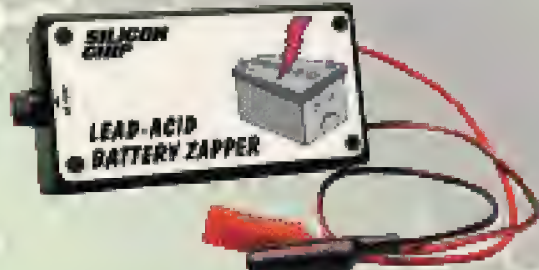
### Lead Acid Battery Zapper Kit

KC-5414 \$23.25 + post and packing

This simple circuit is designed to produce bursts of high-energy pulses to help reverse the effects of sulfation in "wet" lead acid batteries. This is particularly useful when the battery has been sitting for a period of time without use. Kit includes circuit board, case, leads, electronic components, and clear English instructions.



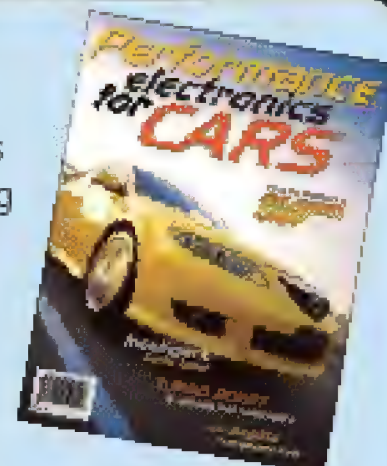
Caution: Battery should be disconnected from the vehicle when using this project



### Performance Electronics for Cars Book

BS-5080 \$14.95 + post & packing

Australia's leading electronics magazine, Silicon Chip, has developed a range of projects for performance cars. There are 16 projects in total, ranging from devices for remapping fuel curves, to nitrous controllers, and more! The book includes all instructions, components lists, colour pictures, and circuit layouts. There are also chapters on engine management, advanced systems, DIY modifications, and more. Over 150 pages! All of the projects described are available in kit form, exclusively from Jaycar. Check out our website for all the details.



Here are just two....

### Universal Voltage Switch Kit

KC-5377 \$18.95 + post and packing

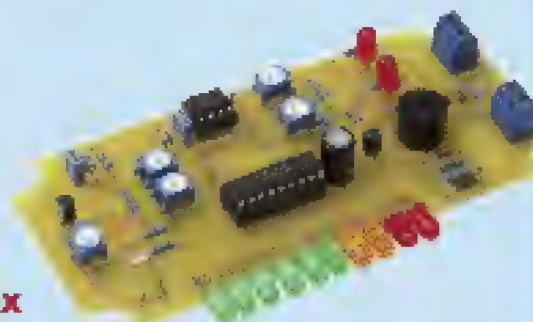
This is a universal module which can be adapted to suit a range of different applications. It will trip a relay when a preset voltage is reached. It can be configured to trip with a rising or falling voltage, so it is suitable for a wide variety of voltage outputting devices eg., throttle position sensor, air flow sensor, EGO sensor. It also features adjustable hysteresis (the difference between trigger on/off voltage), making it extremely versatile. You could use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, and much more. Kit supplied with PCB, and all electronic components.



Recommended box UB2 \$1.95 each



Recommended box UB3 \$1.95 each



### Smart Fuel Mixture Display

KC-5374 \$17.95 + post & packing

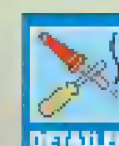
This new 'smart' version has a few additional touches such as, auto dimming for night driving, emergency lean-out alarm, and better circuit protection. Another great feature, is the 'dancing' display which operates when the ECU is operating in closed loop. Closed loop means that the air/fuel ratio is optimum for fuel economy and emission performance. Kit supplied with PCB and all electronic components.

• Car must be fitted with air flow and EGO sensors (standard on all EFI systems) for full functionality.

### Digital Fuel Mixture Display

KC-5300 \$39.95 + post and packaging

Monitor your car's air fuel ratio in real time on a three-digit display as well as on the programmable 10-LED bargraph. The kit will indicate ratios between 11.8 & 20.6 for petrol and 12.7 & 21.5 for propane/LPG. Features include: lean and rich indication, fast 220ms update time for bargraph, 440ms update time for 3-digit display, 0-1V display for setting up adjustments, dot or bar option for bargraph and automatic display dimming for night driving. All this in a case measuring just 3.25 x 2.12 x 1.22 in. Kit includes case with silk-screened panel, PCBs, pre-programmed PIC micro, 7-segment displays, red acrylic, hook-up wire and all electronic components.



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# Instant Replay

## Add a Digital Recorder to an FM Radio

**H**ave you ever been listening to the radio and wished that you had written down the name of a song or an artist's name? Can you even imagine attempting to juggle a tape recorder or reach for a pad of paper right at the last second, only to grab just a portion of this information? You would probably look kinda silly going into the local music store and asking for the latest single by "Green Bay" rather than "Green Day" or trying to purchase "Mr. Backside" by The Killers instead of "Mr. Brightside." Gulp.

Well, here is a circuit design that addresses this issue with great aplomb. "Instant Replay" combines a stock FM radio (for less than \$10.00) with the nifty ChipCorder® IC from Winbond. Consider this article to be a little bit of a hack combined with a serious circuit design and all wrapped up in an elegant form factor. In fact, "Instant Replay" can be combined with a lot of other personal electronics, as well. Therefore, there is tremendous latitude

for modification of the article's concepts.

First of all, what's with this ChipCorder thing? ChipCorder is a digital, single-chip tape recorder that can provide high-quality playback without the need for battery backup circuits (see Figure 2). This incredible chip requires only a handful of support components to record messages up to 40 seconds (e.g., for the I16xx Series) in duration and then play the message back on a standard eight-ohm speaker. Additionally, Winbond claims that the message has a retention of 100 years, can be overwritten 10,000 times, and can cost less than \$20.00 (depending on the exact ChipCorder series device).

Chances are that you might already have a ChipCorder in your house, right now. Many promotional key chains, picture frames, greeting cards, and stuffed toys that speak high-quality human phrases use ChipCorder devices for playback. Even some warning alarms in automobiles and industrial control centers rely on ChipCorder for signaling a clear and understandable signal. "Hey stupid, STOP" gets a person's attention a lot better than "Beep, beep."

The maker of ChipCorder — Winbond Electronics Corporation America, a wholly owned subsidiary of Winbond Electronics Corporation of Hsinchu, Taiwan — is based in San Jose, CA. Started in 1990, the American branch began distributing signal conditioning devices for consumer and industrial markets. With the 1998 acquisition of Storage Devices, Winbond America quickly became a market leader in silicon voice recording and playback IC solutions — namely, ChipCorder. Additional acquisitions of Bright Micro Electronics and the Thin Film Transistor (TFT) LCD division of Cirrus Logic®, based in Austin, TX further entrenched Winbond America's contribution to award-winning voice and speech chip solutions and state-of-the-art TFT LCD-driver ICs.

Four new product lines are aimed at bolstering Winbond America's speech products: the WTS70X series, the industry's first single chip IC solution that converts Text-To-Speech (TTS); the W68xx series, a family of voice CODEC chips aimed at telephony, communications, and consumer applications;

**Figure 1.** The completed Instant Replay looks ready for listening to the big game, doesn't it?



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the WMS72xx series, a family of 256-tap, nonvolatile, digitally programmable potentiometer ICs aimed at communications, industrial, and consumer applications; and the I16xx ChipCorder series of single message record/playback ICs.

The I16xx is the first series of ChipCorder devices designed to operate from 2.4V to 5.5V. Furthermore, the I16xx series features 6.6 to 40 seconds in record/playback duration, pushbutton operation, LED indicators, nonvolatile message storage, and an integrated speaker driver, which provides both PWM and current-mode speaker outputs. By varying a user-determined external oscillator resistor, the I16xx series (1610, 1612, 1616, and 1620) can be programmed for a 4 to 12 kHz sampling frequency. Likewise, this variable sampling frequency also determines the length of recording time. Finally, this is a fully integrated system-on-a-chip with support functions that include: AGC, microphone preamplifier, speaker drivers, oscillator, and memory. All of this in a neat 16-pin DIP. Perfect for hacking into an FM radio.

In this hack, we are going to turn an ordinary FM radio into a digital message center. By inserting a ChipCorder I1610 device (with support components) inside a radio, you can instantly record a short message that can be played back on command. If you elect to switch to a different ChipCorder series IC, you can add several of these digital recording devices in series and make a variety of messages that can be individually played back. You are only limited by the space available inside your selected FM radio (or other electronic project).

## Hacking Instant Replay

**Step 1. Cracking this Oyster.** Opening up my cheapo FM radio was incredibly easy (see Figure 3). I just had to remove one screw and pry it apart with my fingernails. Be forewarned, however, I have seen some inexpensive radios that have the cases glued shut. If this is the case with your radio, use a small knife blade for cutting away the glue from the plastic. Then you can glue everything back together again when you're finished with your "Instant Replay" hack.

**Step 2. Opt for the Pre-Made Board.** If you want to save yourself some time, you can purchase a ready-made ChipCorder recording board (see Figure 4). Just install this board inside the radio, attach a power supply, and connect its output to the radio's earphones socket or speaker terminals. Otherwise, you can easily and inexpensively wire your own board. Whichever circuit you choose, beware of electric short circuit. Insulate your ChipCorder with some inexpensive antistatic foam.

**Step 3. Let Your Fingers Do the Recording.** At the least, you can build a ChipCorder circuit with only two pushbuttons — one playback (e.g., either PLAYL; level activated or PLAYE; edge activated) pushbutton and



**Figure 3.** While the prices of these radios are great for hacking, they don't have the best performance. So buyer beware.



**Figure 2.** Some ChipCorder family members. The two top ICs are I16xx series chips (e.g., I1610 and I1620, respectively), while the third one down is ISD5116 and the bottom IC is ISD4004.

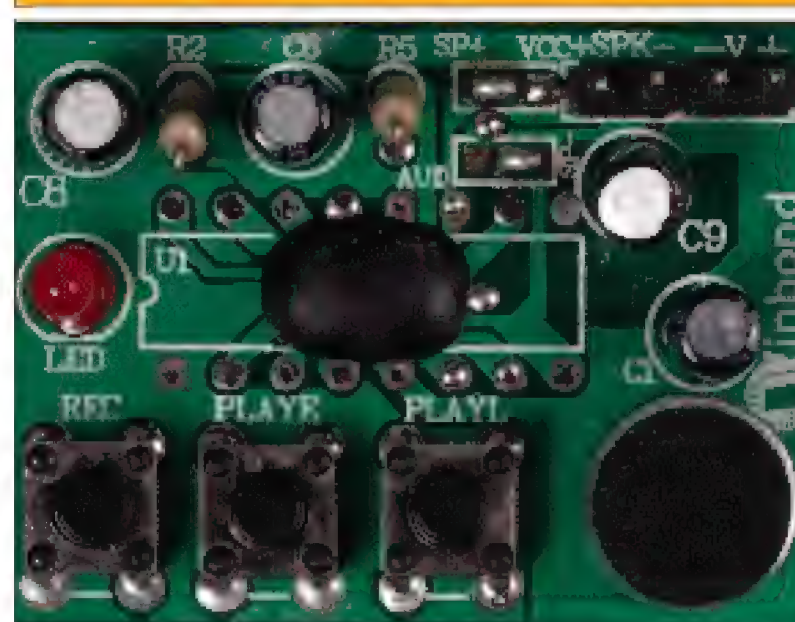
one record pushbutton. Or, you can add three pushbuttons. In this hack, you could use a single edge-activated playback pushbutton along with one record pushbutton.

While we're on the topic of choosing your interface, you might want to consider adding a separate power switch for the ChipCorder circuit. Otherwise, the recorded message will only play during operation of the radio. This could be distracting. I had to omit this switch from my "Instant Replay" due to space limitations — there wasn't enough room inside the radio's case for holding another switch. You might have better luck, however. If so, be sure to

## What Went Wrong

While there aren't very many components in a ChipCorder circuit, the wiring can be somewhat tricky. Double and triple check your wiring. If you think that the FM radio speaker and/or your own microphone connections are at fault, attach a spare eight-ohm speaker to the ChipCorder circuit's output for checking the speaker connection and another spare electret microphone to the MIC input for verifying the microphone connection. Finally, use your multimeter to make sure that the ChipCorder IC is receiving ample power. The different members of the ChipCorder family have differing power requirements. Refer to the ChipCorder Family Members sidebar for more information.

**Figure 4.** This prebuilt Winbond I16xx evaluation board is great for quickly adding an "Instant Replay" recording circuit to any electronic project.



**Figure 5.** My "Instant Replay" circuit had to be mounted externally on my FM radio.







**Figure 6.** After you remove the belt clip, there are two “stabilizing” alignment holes that can be used for routing all of the circuit’s wiring inside the radio.



**Figure 7.** Never throw anything away. This salvaged helmet from a Robosapien can be used for hiding and protecting the external “Instant Replay” circuit. I used Teflon® washers for connecting the visor to the helmet. Therefore, the “slippery” washers enabled the visor to be moved up and down for accessing the radio’s battery compartment.

include a separate power switch.

You can either mount your pushbuttons externally or internally. Duh? The mounting decision will be based on the amount of space that you have inside the radio. My selected radio had no space for internally mounting the pushbuttons, so I had to come up with a method for “tastefully” integrating three micro SPST buttons along with my entire ChipCorder circuit onto the radio’s exterior case (see

## Parts List

The Hack — Add a ChipCorder message center to an FM Radio.

**What You Will Need:** A ChipCorder IC (e.g., ISD1212), (2) 4.7 mF capacitors, (4) .1 mF capacitors, (2) 1K resistors (brown-black-red), (2) 4.7K resistors (yellow-violet-yellow), 80K resistor (gray-black-orange), LED, (3) micro SPST NO momentary pushbuttons, and one FM radio (\$2.99; Walgreens) (see Schematic 1).

Approximate Cost: \$12.65.

Time Needed: 16 hours.

Figure 5). Just such a spot was found on the radio’s underside. I had to eliminate the supplied “belt clip,” however. This omission was more a blessing than a loss — the belt clip wouldn’t stay “clipped” to anything, including my belt. And, as shown in Figure 6, the two mounting holes for this belt clip were ideal for running the speaker and power supply wiring inside the radio.

In order to protect my external “Instant Replay” circuit, I glued a “spare” Robosapien helmet to the underside of the radio. This helmet had been removed from a Robosapien for a video camera hack that was included in my book *The Official Robosapien Hacker’s Guide* (TAB Electronics, 2005). By using some 4-40 hardware (two bolts, four washers, and two nuts), I was able to secure the old Robosapien visor to the helmet as a movable cover (see Figure 7). This cover did a good job of hiding the ChipCorder circuit, as well as protecting it from accidents. Then, as needed, raising the cover enabled the batteries to be changed (see Figure 8).

**Step 4. Speaker in the House.** Wire the SP+ and SP- speaker output from the ChipCorder circuit into the external headphone port of the radio. You will then hear your recorder through your radio’s headphones (or, ear buds).

**Step 5. MIC Check.** A small discrete electret microphone



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## ChipCorder Family Members

Each of these ChipCorder series consist of a complete “system on a chip” set of components. Only a speaker, microphone, several passive components, and a pushbutton interface are needed to make a digital recording/playback system. More advanced members of the ChipCorder family are better suited to microcontroller and/or computer control.

Series Pkg	Operating Range	Duration
ISD11xx	28-pin DIP 5V	10 sec
ISD12xx	28-pin DIP 5V	12 sec
ISD14xx	28-pin DIP 5V	20 sec
116xx	16-pin DIP 3V	40 sec
ISD25xx	28-pin DIP 5V	2 min





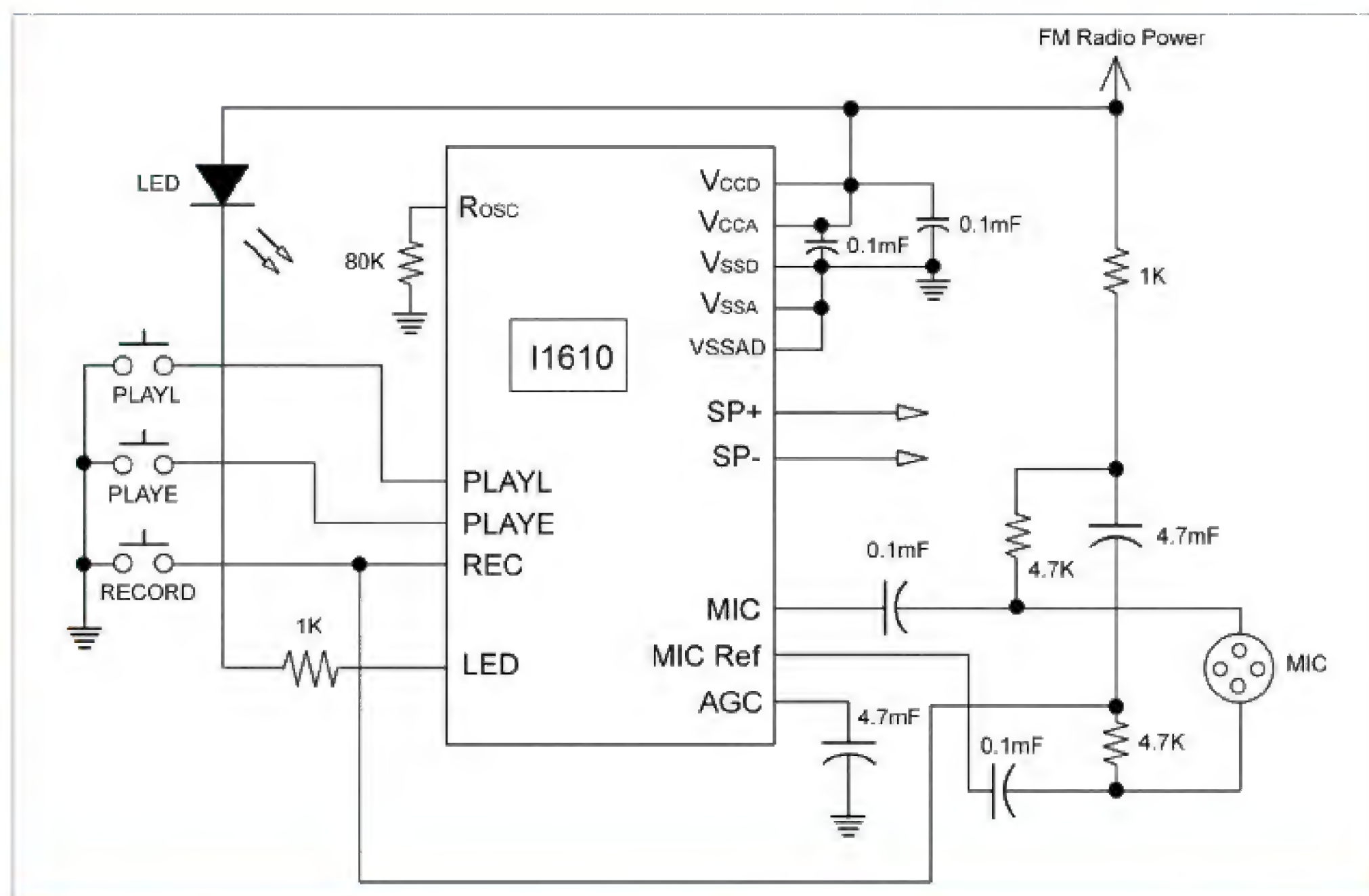
**Figure 8.** Ready to go; just install some batteries and connect a set of external headphones for testing "Instant Replay."

will be used for the MIC input on the ChipCorder. Two connections must be made to this input — output and ground.

## Step 6. Power to the Circuit.

Attach a battery pack to the ChipCorder circuit. If you are able to locate the new I1610 IC, however, you can drive the circuit straight off of the FM radio main circuit board. Alternatively, you could use a small coin-size 3V lithium battery for powering an I16xx series ChipCorder. Install batteries in the radio and make a sample recording. Now play back your recording.

**Step 7. Looking for Mr. Brightside.** If both recording and playback check out okay, put everything back together and start making some great song notes. At least now you won't look like an "American Idiot" next time you go to the local music store. **NV**



**Schematic I.** The "Instant Replay" circuit.

## About the Author

Dave Prochnow is a frequent contributor to *Nuts & Volts* and *SERVO Magazine*, as well as the author of 25 nonfiction books including the best selling *Experiments with EPROMs*. Dave also won the 2001 Maggie Award for the best "how-to" article in a consumer magazine. Working with Mark Tilden, Dave has just finished assembling an enormous selection of robot tips, programs, and hacks into his forthcoming book, *The Official Robosapien Hacker's Guide* (TAB Electronics, 2005). You can learn more about this book and other robotics/electronics projects at Dave's website: [www.pco2go.com](http://www.pco2go.com)

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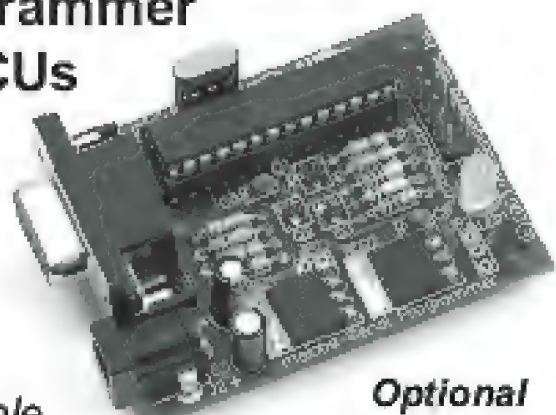
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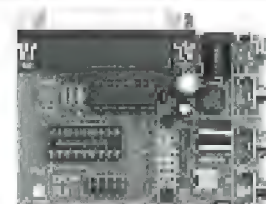
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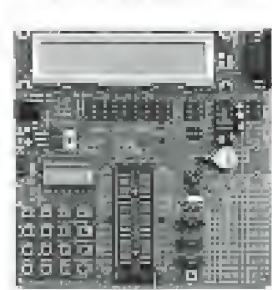


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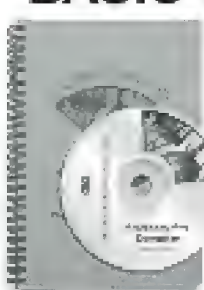
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for Near Space endeavors. This would apply both to all active Near Space enthusiasts and to yourself. By printing columns giving advice on the activity, and especially by giving everyone the ability to associate themselves with you by using the logo you've designed (which is quite nice, by the way), you might be opening yourself up to lawsuits for any Near Space craft that damages anyone's property or worse, hurts someone on re-entry. I say all this in a spirit of a fellow (even though inactive) enthusiast for a new hobby that you are creating almost single-handedly, it seems; it would be a shame to have it become aborted in such a short time due to someone being sued — or because someone becomes careless and does cause any damage or harm.

So, I wish you good luck in the future of your new hobby, and hope you will look into this topic so that people who engage in it can learn how to protect themselves against potential liability.

**Howard Mark**

*Near Space groups use software to predict balloon flights. With this software, we can keep the near spacecraft from landing in a town or other high risk environment. The parachute used to recover the near spacecraft lands it at about 10 mph. The near spacecraft also carry audio beacons that can be heard over 100 feet away. About the only risk we run is scaring cattle when they hear the near spacecraft landing.*

*The National Weather Service and military launch over 100 weather balloons per day. In over 50 years of launches, there is yet to be an incident of a balloon harming a person or their property during the launch, flight, or landing.*

*My book (on the Parallax website) discusses how to safely fly near spacecraft. However, you bring up a good point so I may write something up for N&V to put peoples' minds at rest. You're right, there are too many people ready to*

*sue at the drop of a hat. But I think model ariplane and rocketry people are taking far larger risks due to the speed and mass of their toys. The fact that there are more of these toys out there also increases their chances of an accident.*

*A couple of near space groups have liability insurance. This is a topic I need to investigate more and I think it would make for a good article. The problem is that researching it takes me away from the science side and moves me closer to the dark side (lawyers!). Thanks for your comments. I hope you enjoy the articles and get a chance to go to a launch sometime.*

*Onwards and upwards, Paul*

*Dear Nuts & Volts:*

Talk about unbalanced. Ed Driscoll's article in the July 2005 issue about blogs is an advertisement for rightwing blogs. Regarding the blogs you feature; you claim Instapundit is moderate? And Powerline is the premier rightwing blog. Hugh Hewitt is clearly right of center. Check out Technorati for the most popular blogs.

Among the top 10 are DKos (3rd), Talking Points Memo (7th), and Eschaton (9th). Three of the top 10 are liberal blogs, only one is conservative, the rest are pop culture or technical blogs. Powerline only comes in 21st, and Hugh Hewitt is 41st, just two above Baghdad Burning.

Even though N&V is a technical magazine, Ed did not even mention any of the hundreds of technical blogs (Gizmodo and Engadget), two of which are in the top 10. I feel Ed is obviously just pushing blogs that carry his viewpoint. However, not all the readers of N&V share that POV.

To the folks at Nuts & Volts, if you can't refrain from partisan politics in a hobby magazine, you are going to lose some of your readership. N&V is where I go to relax, to get away from politics. It's a shame I had to put up with this clearly partisan piece. You can visit my blog at <http://crobserver.blogspot.com>

**Peter Houlihan**



# The CompuColor II

## A Forgotten Home Computer

by Tom Napier

If the home computer can be said to have had a Golden Age, it ran from the late 1970s to the early 1980s. Back then, there were dozens, if not hundreds, of computers from which to choose. Magazines compared brand-to-brand, operating system-to-operating system. Beginners laboriously typed 20-line Basic programs into their Sinclair ZX-80s. The computer geeks had S-100 systems running CP/M on Z-80s, spending half of their spare time and all of their spare cash plugging in new boards. The rest of us bought more domesticated computers, whose works were hidden inside the case that held the keyboard. Everyone used a TV as a display, despite the poor resolution inherent in its RF interface.

Those who were more affluent bought that super-commodity computer, the Apple II. They were inordinately proud of its ability to display three colors and to run programs not only from a cassette recorder, but also from an add-on floppy drive. Back then, when a 10 MB hard drive cost as much as a small automobile, a 5-1/4" floppy drive was every computer hobbyist's greatest aspiration.



PHOTO 1. The CompuColor II, in all its simulated wood-grain glory, had more keys than one knew what to do with.

### ENTER BIG BUSINESS

The Golden Age ended not long after IBM introduced their personal computer. Initially, you had to own a company in order to afford one, but the demise of the home computer had begun. The days when you could showcase your individuality and inventiveness by manufacturing computers in your garage were over.

Oh, there were spurts of resistance. The Macintosh appeared, achieved a dedicated following, and still survives in mutated form. For several years, the Commodore Amiga was the most capable desktop computer on the market, but Commodore's marketing geniuses went

astray and the PC ultimately developed equally powerful graphics. Although the Amiga still has fervent fans, as a commercial product it is long gone. Today, there may be competition in the computer market, but there is essentially no choice. As Henry Ford said of the Model T, "You can have any color you want, so long as it's black."

### MY FIRST COMPUTER

Throughout 1977 and 1978, I developed a site-wide radiation monitoring system for CERN, the European particle accelerator laboratory. I achieved unheard-of flexibility and features by substituting an 8080-based microcomputer board for the racks of TTL chips that had previously been used. I developed



the software on a system whose three plug-in memory cards stored a total of 12 KB and had cost my employers \$4,000 apiece.

In 1979, I finally bought a computer of my own. Right from the start, I'd decided to buy the best home computer available and to stick with it. That's why I picked the Compucolor II. It left all its contemporaries in the dust, yet today, virtually no one has ever heard of it. I was still using mine in 1987, when I bowed to the inevitable and bought an Amiga 500. In 1992, I upgraded to the Amiga 3000 I still use. As I said, I stick with the best.

## BOTTOM UP OR TOP DOWN?

Early home computers were designed from the ground up. Developers introduced new features as fast as they could design them, and customers gobbled them up. You started with a minimal, barely usable machine with integer Basic and scarcely enough memory to run it. You fought the family for use of the TV as a display device and you struggled to get programs to store and load on an audiocassette recorder. Eventually, you'd expand the RAM capacity, buy a floating point Basic, or even add a disk drive. The TV remained the only display option. Dedicated computer monitors were rare, hugely expensive, and monochrome. Besides, the RF output from your computer wouldn't drive one.

The Compucolor II bucked this trend. For a start, it was designed not by a bunch of enthusiasts working on a shoestring, but by an offshoot of the Intelligent Systems Corp., a commercial computer and monitor company. Rather than adding on to a minimal system, its designers scaled down a professional product. By the standards of the day, its floating-point, graphics-capable Basic was a marvel and its development was already paid for.

The Compucolor's plastic case had been designed for a 13" portable TV (see Photo 1). Where you'd expect to find the TV's tuner, there was a 5-1/4" floppy disk drive. Down the other side of the CRT was the chassis that held the power supply and the line and frame scan circuitry. Under the tube, you'd find the computer board

with an 8080 processor and from 8K to 32K of RAM. Its 16K of ROM held the disk operating system and Basic.

RAM could be extended to 40K with an add-on board. The advantage to an add-on was that neither Basic nor the operating system was aware of its existence. It was the perfect place to run your own assembly language programs without fear that they might be overwritten. Photo 2 shows the motherboard with two add-on memory boards — one static and one dynamic.

At a time when most home computers had rubber membrane keyboards that were cumbersome and inconvenient, the Compucolor had a real keyboard with real keys. It was a standard Intecolor part, a solidly built unit linked to the computer with a ribbon cable about four feet long. You no longer needed to perch the TV on top of the computer and sit with your nose a foot from the screen. Basic keywords could be entered with single keystrokes.

## A REAL DISPLAY

Apart from being the only home computer of its generation whose disk drive wasn't an optional extra, the Compucolor's distinction was its built-in display tube with direct RGB drive. Not only did you have higher resolution than computers driving TV sets, but you also had eight colors and full saturation, rather than the limited range of pastel shades that the Apple II could manage. I used to show mine off at computer clubs; its dazzling color display blew people away.

The character generator limited you to upper-case-only, but you could display 64 characters on each of 32 lines. Other computers could only manage 40 characters by 24 lines. Each character had an attribute byte that let you choose any two of the eight colors for a character's background and foreground. You soon learned which combinations were readable and which ones were not.

Because any character could be replaced by a 2x4 pixel block, you could plot graphs with

128 x 128 resolution. The built-in Basic had a full set of point-and-line plotting functions.

All of the pixels in a block shared the same color. If you wanted control over the colors of individual picture elements, you had to settle for 64x64 blocks of four pixels each.

## AND A DISK DRIVE, TOO!

The Compucolor's 5-1/4" disk drive was completely non-standard. It read and wrote data using a TMS5501 timer/port/UART chip in its high-speed test mode. Each disk stored 51,200 bytes as 400 blocks of 128 bytes — probably the lowest disk capacity of any commercially available computer. You doubled it by flipping your disks over and putting another 400 blocks on the back. This procedure worked most of the time, even though disk-drive experts condemned it.

The disk operating system was a masterpiece of simplicity. Each disk had a number of blocks allocated to its directory, as selected by the user; each block addressed six files. Each file occupied a contiguous area of the disk. If you edited and saved a file, it was automatically assigned a new version number and appended to the disk and the directory.

The fun started when you deleted an unwanted file. Unlike the modern approach of marking disk blocks as deleted and writing new files in

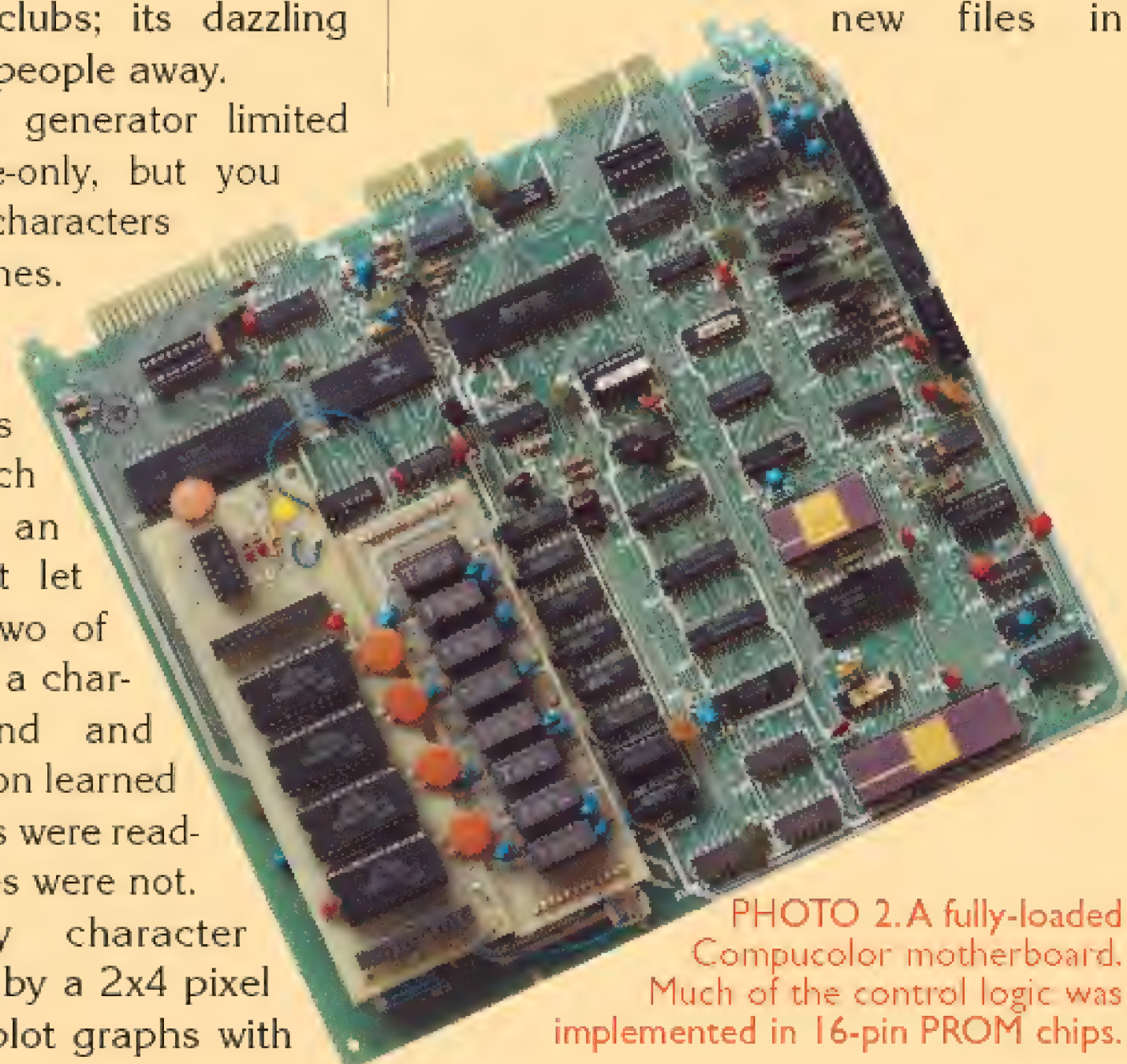
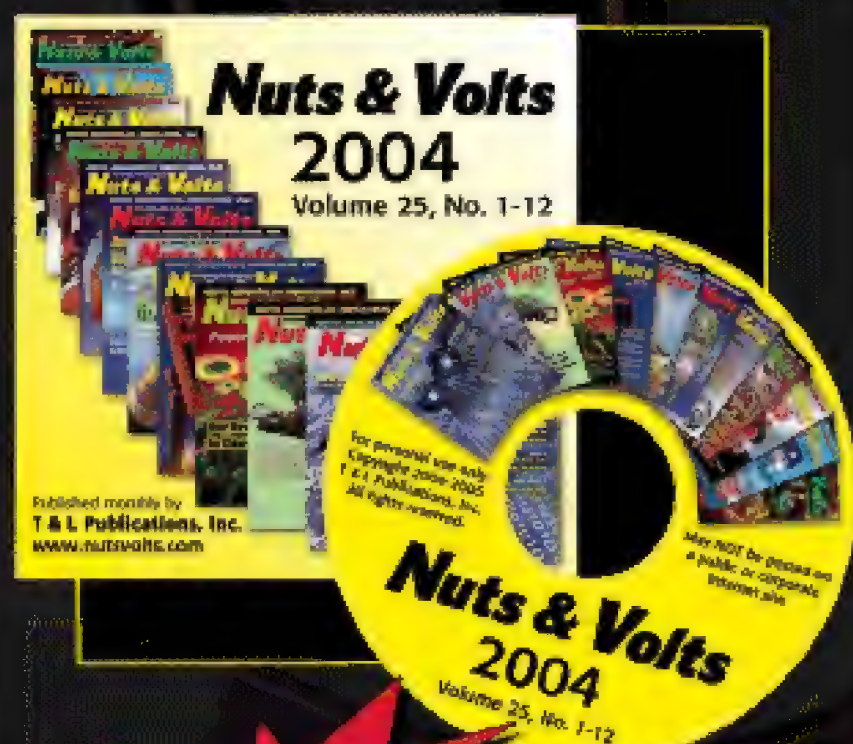


PHOTO 2. A fully-loaded Compucolor motherboard. Much of the control logic was implemented in 16-pin PROM chips.



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scraps scattered all over the disk, the Compucolor simply moved up all the newer files on the disk to fill the gap. If you didn't mind the wear and tear on the disk, this was actually quite a good solution; there was never any file fragmentation on a Compucolor.

Of course, this approach meant copying files, or sections of them, into the computer's memory while moving them. To avoid interfering with programs in RAM, the Compucolor was smart enough to use the 4K video RAM as a file buffer. Deleting a file became something of a visual delight. For seconds at a time, as disk blocks were copied first to the screen RAM then back to the disk, large portions of the display were taken over by constantly changing random graphics characters.

## FLAKY DISKS

One side effect of the file copying process was that it graphically illustrated, quite literally, just how recalcitrant disk operation could be. A line of graphics would flicker for several seconds while the software read and reread a disk block until it got a version that agreed with the check-sum on the disk. That block would then be written and the nail-biting process would recommence with another block further down the file.

Unreadable disk blocks were such a fact of life that I wrote a little Basic and machine-language program that let me read a specific block, edit out errors, and rewrite it to the disk. This would usually restore an unreadable file. A popular after-market product was a mu-metal screen that could isolate the disk drive from the nearby scan coils of the CRT. I drilled a hole in the side of the computer's plastic case, which let me adjust the drive's rotation speed on the fly and get the best results from a reluctant disk.

When I found that I was replacing line-scan transistors on a regular basis, I made another modification: a fan bolted above the power supply. I've not risked powering up my Compucolor in its original form since I stopped using it. On the rare occasions when I use it to read old files, I connect the motherboard and disk drive to an old Commodore power supply and a Commodore RGB-input monitor.

## SOFTWARE

When I bought my Compucolor, a decent range of software was already available, including a text editor, an 8080 assembler, and a number of games. I bought the chess program. Ultimately, I got it to run 40% faster by modifying its internal board representation. When programs were 8K long, one could do things like that. Imagine modifying one of today's humongous game programs to suit yourself!

I used both the text editor and the assembler extensively. I eventually modified the editor to display upper and lower case characters as different colored upper-case characters on-screen. When I coupled up a dot matrix printer, I got normal upper- and lower-case text. I eventually substituted a daisy-wheel printer and added features such as micro-justification to the editor. My text has never looked better.

## THE MARKET HAS ITS WAY

As I've indicated, the Compucolor had its limitations, largely resulting from its relatively low cost. By 1979, the 8080 was passé, and those still using it wanted to run CP/M. Despite its features and technical ingenuity, the Compucolor II never became a big seller. Presumably, potential users balked at having to come up with the price of a complete system before they could get started. There was an active user group that had a newsletter, *Colorcue*, to which I used to contribute, but no mass following.

Then, in 1981, the FCC introduced new regulations governing the permissible level of RF radiation emitted by home computers. A TV set in a plastic case was governed by one set of rules. Call it a computer, though, and a different set of rules applied. It was no longer possible to get away with an unshielded case and ribbon cables carrying high-speed signals. Updating the Compucolor wouldn't have been worth the cost.

FCC regulations or not, I got good service from my Compucolor II for another six years. It is a fine example of a technological achievement that failed in the marketplace. **NV**



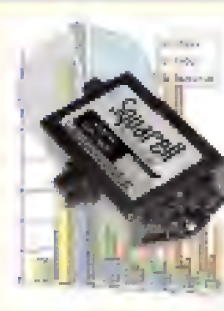
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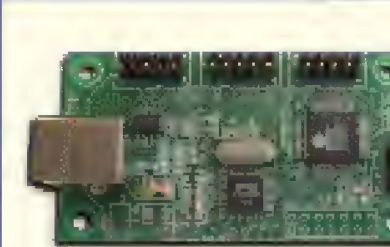
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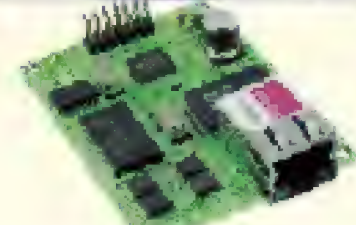
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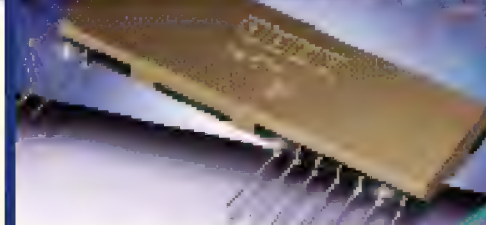
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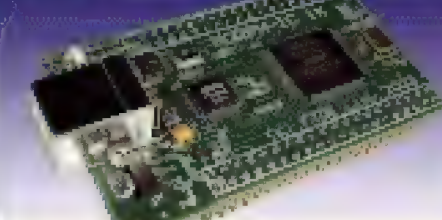
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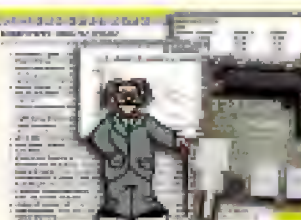
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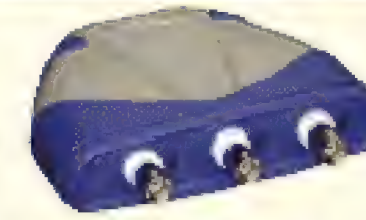
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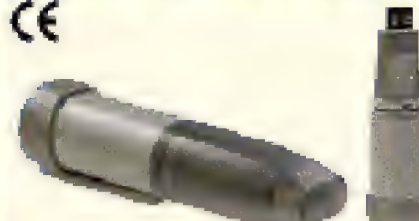
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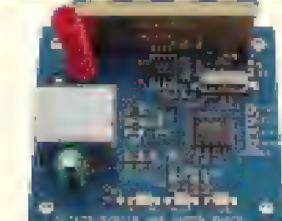
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## Robotic Baseball-Catching Claw

The Ishikawa-Namiki Komuro Laboratory in Japan has designed a claw device that can catch baseballs up to 186 mph. This claw will predict the ball's movement and trajectory to allow for it to catch when being thrown at different angles.

The robot does not need a catching mitt. It resembles a single metallic claw, with just three fingers instead of the human complement of five. An array of 32 x 48 individual photo detectors in its "palm" tracks a ball's trajectory at high speed. A series of specialized image processing circuits recognize this movement almost instantly.

An approaching ball triggers the robot's three fingers into action. Actuators embedded in each joint use a burst of high current to move through 180 degrees in less than one tenth of a second. This enables the machine to snatch the ball in the split second it takes to arrive.

## Kyocera KX16 offers Mobile Gaming with Alienware Gamepad

The Kyocera Candid KX16 is a color clamshell phone that can be converted into a mobile gaming handset and will be targeted to International and US CDMA carriers. With a style and affordability that will appeal to many users, the features include external caller ID, VGA camera with flash and digital zoom, speakerphone, voice-activated dialing, and a raised keypad for increased texting speeds.

The camera features a front-facing lens and flash which allows you to snap a photo quickly while moving without the worries of blurring. A five-step digital zoom goes from 160 x 120 resolution to 648 x 480. It also supports multi-shot mode, auto-focus, self-timer, white balance, color effects adjusting, and fun frames. With the Alienware game pad, the KX16 will allow its users to play Java or BREW games with a more console-style feel to it. The Alienware Gamepad is due out this fall and will sell for \$29.95, however the Gamepad will be bundled with the KX5 Slider before the KX16 hits the street.

## New Roomba Cleans on Schedule

Robot's next major goal for its Roomba vacuum is for it to become more invisible in the household. Sounds counter-intuitive, but that's the reasoning behind the popular home vacuuming robot's next major update, which adds a set-it-and-forget-it scheduling capability.

Nearly three years after it was first introduced, the Frisbee-shaped Roomba robot vac robot has become

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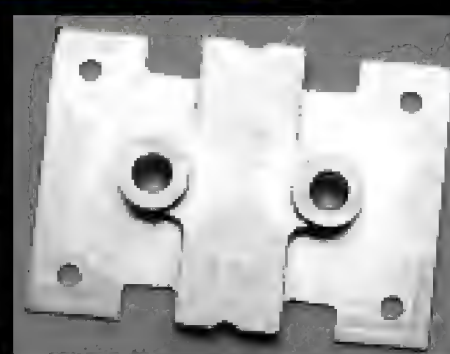
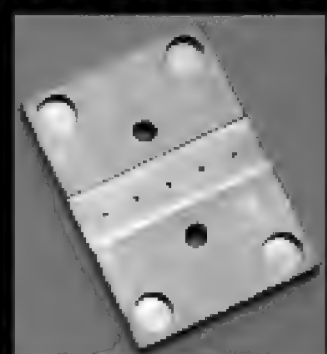
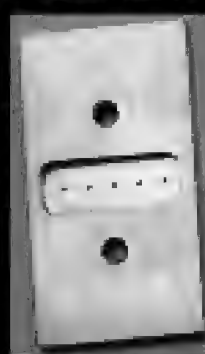
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The Colorado law affects teens with restricted licenses — brand-new drivers who must have an adult drive with them for a year. Police can issue a citation only if the driver is stopped for another violation.

This year, 38 states tried to pass legislation restricting cell phones, mostly focusing on younger drivers. Bills were passed or are still being considered in 22 states, according to the National Conference of State Legislatures in Denver.

So far, only New York, New Jersey, the District of Columbia, and Connecticut prohibit the use of handheld phones while driving, though other states have adopted limited restrictions for young drivers or school bus drivers. Most states are looking at limited bans because it is unclear and a bone of contention with the telecommunications industry — whether cell phone use while driving can be tied to more accidents.

SEPTEMBER 2005

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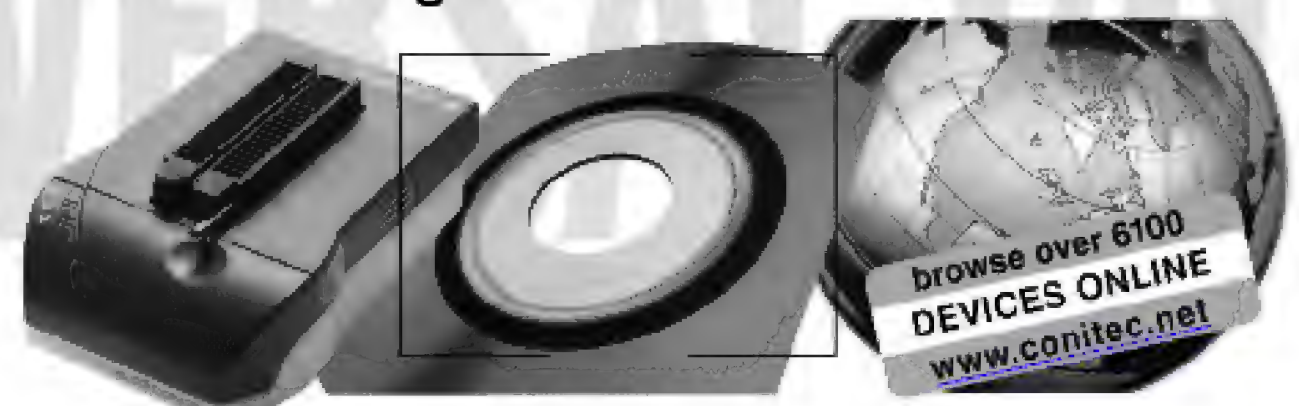
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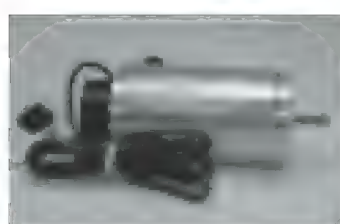
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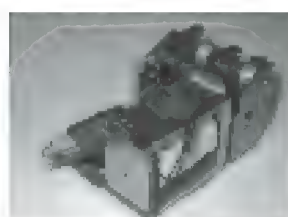
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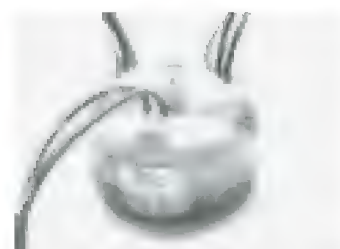
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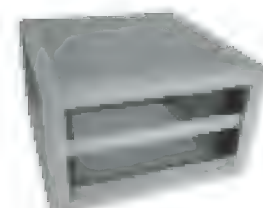
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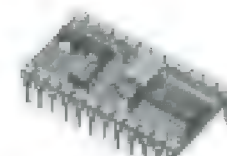
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# CAPACITORS

## *The Family Tree*

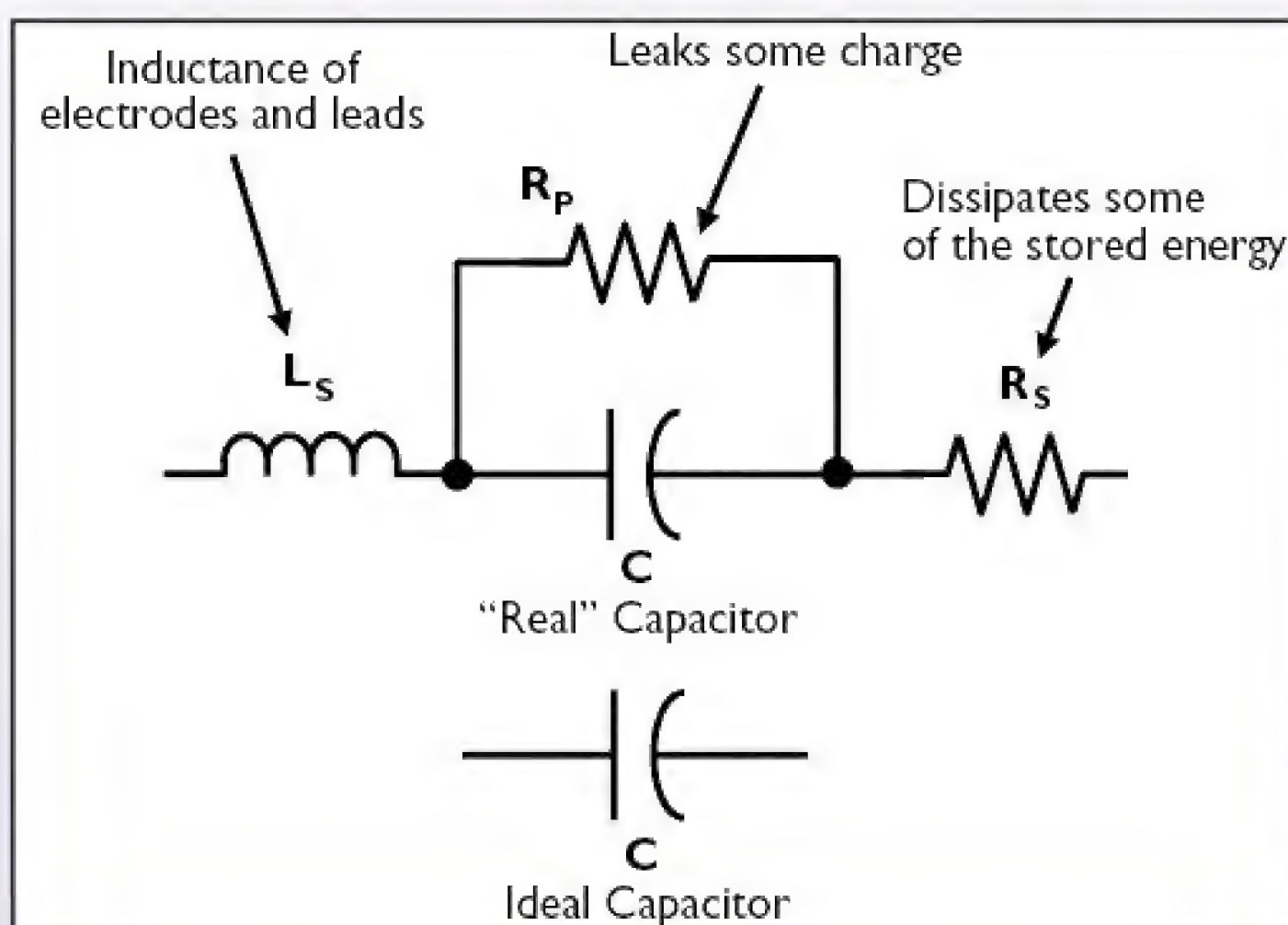
by H. Ward Silver



**O**pen a parts vendor's catalog to the capacitor section and you'll find an amazing variety of choices. Why are there all these different types? Rest assured that there are perfectly good reasons for each. In this article, I'll explain why and how to tell what type is right for your project.



## CAPACITOR FUNDAMENTALS



**FIGURE 1.** The model for a real capacitor includes inductance and loss that affect its performance.

A capacitor is just a pair of conducting plates (electrodes) that are separated by an insulator (dielectric). When voltage is applied, electrons are forced onto one plate and removed from the other, charging the capacitor and creating an electric field between the electrodes. The electric

field's energy is stored in the capacitor's dielectric. All capacitor types are just variations on this general theme.

Capacitance is the measure of the amount of energy that the capacitor stores for a given amount of charge and voltage. The area of the electrodes and the material used for the dielectric determine the capacitor's ability to store energy. More area or a thinner dielectric increases capacitance. Like resistors, a capacitor's value has a certain precision that shows how close the capacitance must be to the labeled or nominal value.

DC will not flow between the two electrodes as long as the dielectric material can withstand the applied voltage. AC is considered to flow between the plates as the electrons flow onto and off of the electrodes. Energy is stored and removed from the dielectric with each half-cycle. Like juggling two balls from hand to hand, there is a lot of energy transferred, but no net change. As the capacitor charges, the building voltage opposes the flow of additional charge. This opposition to current flow is called reactance and is abbreviated  $X_C$ . ( $X_L$  is inductive reactance.)

The materials used to make the capacitor and their physical configuration cause some variation from the ideal capacitor. The size of the electrodes and the leads used to connect them to circuits introduce a small amount of parasitic inductance. Dielectric materials dissipate a small amount of the stored energy. There is also a little leakage current between the electrodes whenever voltage is present.

These extra and unwanted effects are shown in Figure 1 as the model of a real capacitor. The parasitic inductance (called ESL for Equivalent Series Inductance) is represented by  $L_s$ , leakage by resistor  $R_p$ , and dissipation by resistor  $R_s$ . (The 's' and 'p' stand for series and parallel.) This model works well enough to represent capacitors over most frequencies and for all but the most demanding applications.

Parasitic inductance is quite small, from picohenries to a few nanohenries. At DC and low frequencies,  $L_s$  can

### SAFETY IN

## Primary Circuits

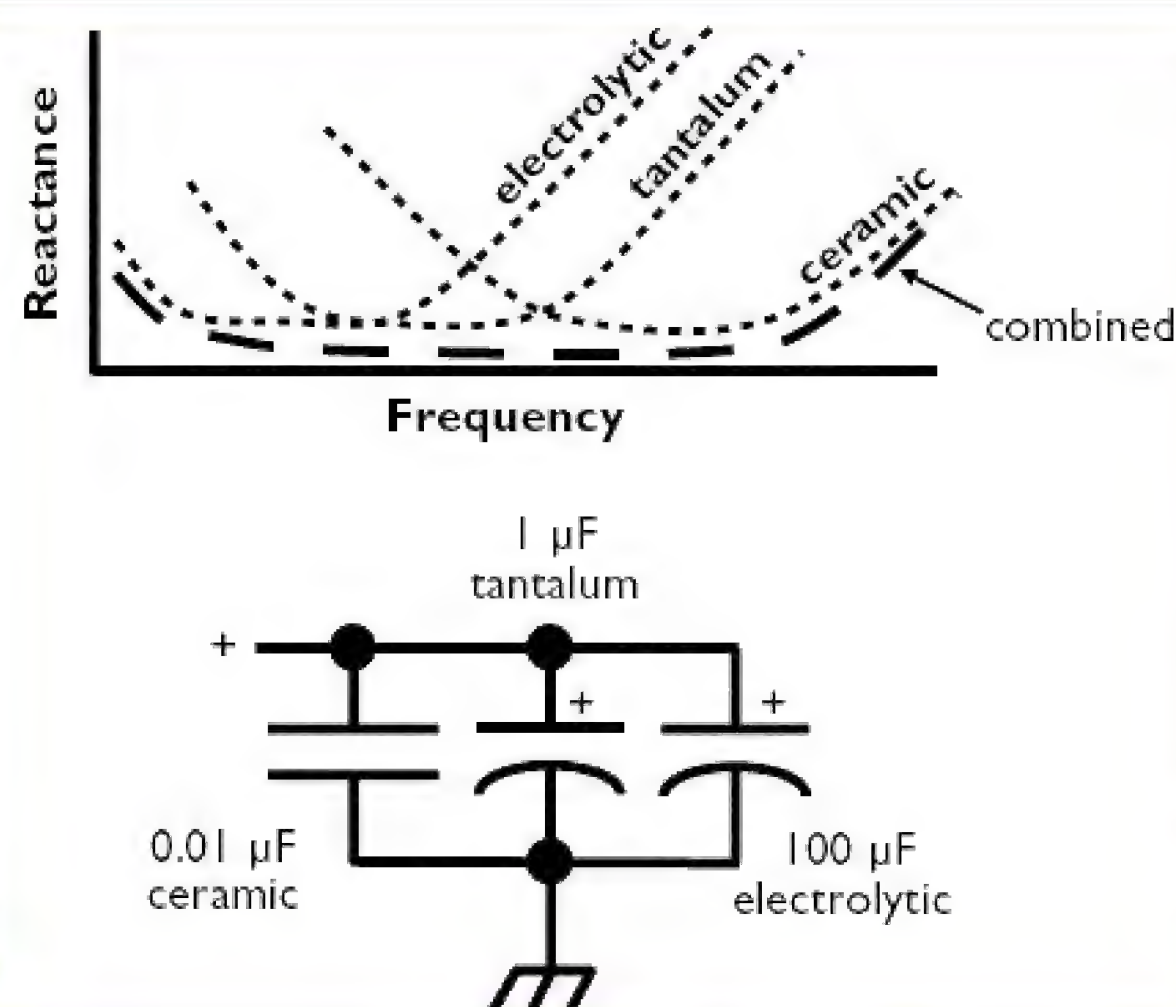
**I**f your application requires a capacitor to connect directly to the AC power line (such as filtering), select a capacitor rated specifically for that use. These capacitors are rated by a safety agency such as Underwriter Labs (UL), CSA (Canada), or VDE (Europe) for "across the line" use. They are designed to be "fail safe" and not cause hazards to equipment users. The additional cost is minimal.

### HOW TO

## Make a Perfect Capacitor

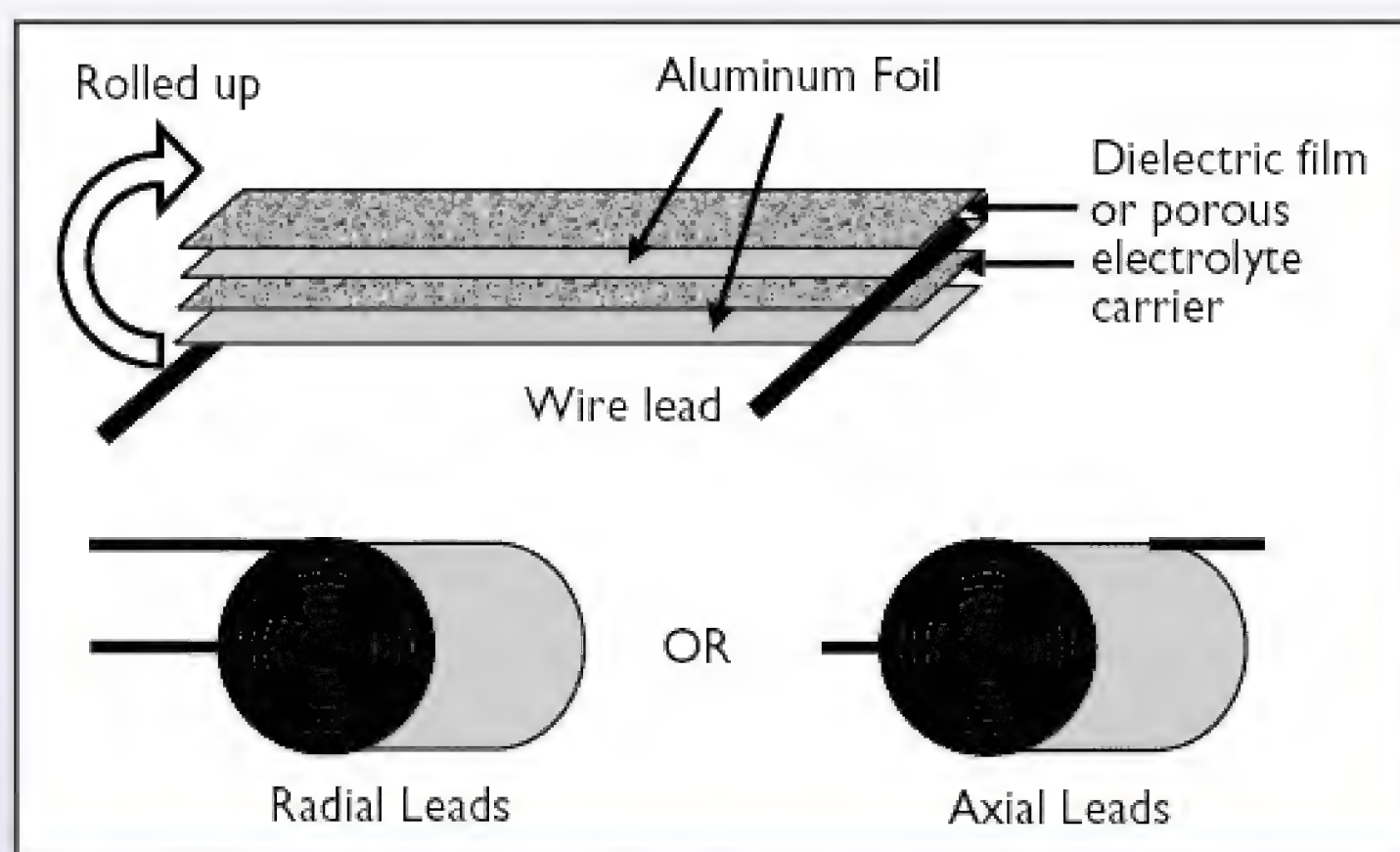
**T**here is no one perfect capacitor type for all applications, but you can make several types share their best characteristics. For example, power supplies for digital electronics need filters that take out everything from low-frequency ripple all the way up to switching transients at hundreds of MHz. Since no single capacitor is suitable, the "perfect" capacitor is made as shown in Figure 2. The electrolytic takes care of low-frequency ripple, the tantalum medium frequencies, and finally the ceramic cap takes care of everything up into the VHF range.

**FIGURE 2.** The "perfect capacitor" is made by combining the best characteristics of three different types of capacitor.





## CAPACITOR FUNDAMENTALS



**FIGURE 3.** Roll capacitors are made from strips of metal and dielectric materials rolled into a cylinder.

be ignored, but as the frequency increases, so does its reactance. In fact, at a sufficiently high frequency,  $L_s$  and  $C$  form a series-resonant circuit. This is the self-resonant frequency,  $f_0$  of the capacitor. Above  $f_0$ , the capacitor acts more like a small inductor!  $R_s$  (also called ESR for Equivalent Series Resistance) acts just like a separate resistor, dissipating a little energy as heat when current flows.  $R_s$  can be as high as several tens of ohms, but is generally only important when the capacitor current is high.  $R_p$  provides a leakage path for current across the dielectric and is typically in the megohms. You can ignore

### HOW BIG

### Is a FARAD?

One farad (1 F) is a large value as capacitors go, but what does that mean? Well, if a 1 F capacitor is charged up to 12 V, it contains enough energy to accelerate a 165-gram Frisbee™ to 67 miles per hour! That's a pretty stiff toss! Similarly, to get that 1 F of capacitance, two plates separated by air and only 1/10 mm apart would have to be 11,300,000 square meters in area! That's 4.36 square miles!

$R_p$  except in very low-power and high-impedance circuits.

There are two common ways of efficiently making capacitors: the Roll and the Stack. Figure 3 shows a typical roll capacitor — two strips of very thin aluminum foil separated by a dielectric. After leads are attached to the foil strips, the sandwich is rolled up and either placed in a metal can or coated with plastic. Radial leads both stick out of one end. Axial leads stick out from both ends along the roll's axis. Because of the long rolled strips, the roll capacitor's  $L_s$  is high.

## Temperature Coefficient

The materials that make up a capacitor expand and contract with temperature, meaning that the capacitance changes with temperature, as well. In many applications, such as IC bypassing or DC blocking, a change of a few percent is of no concern. However, in a timing circuit or an oscillator, it's a big deal!

A capacitor's change in value with temperature is called its temperature coefficient or tempco and is denoted by an industry standard code. (The nominal value is specified at 25°C.) The three most common tempcos are:

Z5U = +22%/-56% change over -10°C to +85°C

X7R = ±15% change over -55°C to +125°C

NP0 = 0±30 ppm/°C over -55°C to +125°C

As you can see, the Z5U rating allows quite a bit of change, but these are inexpensive capacitors used for garden variety applications or where temperature won't be changing much. The NP0 (that's a zero, not a capital O) capacitors are only used where holding a steady value is important. You can find a nice display of temperature coefficients at [www.niccomp.com/Products/TC\\_Ceramics.pdf](http://www.niccomp.com/Products/TC_Ceramics.pdf)

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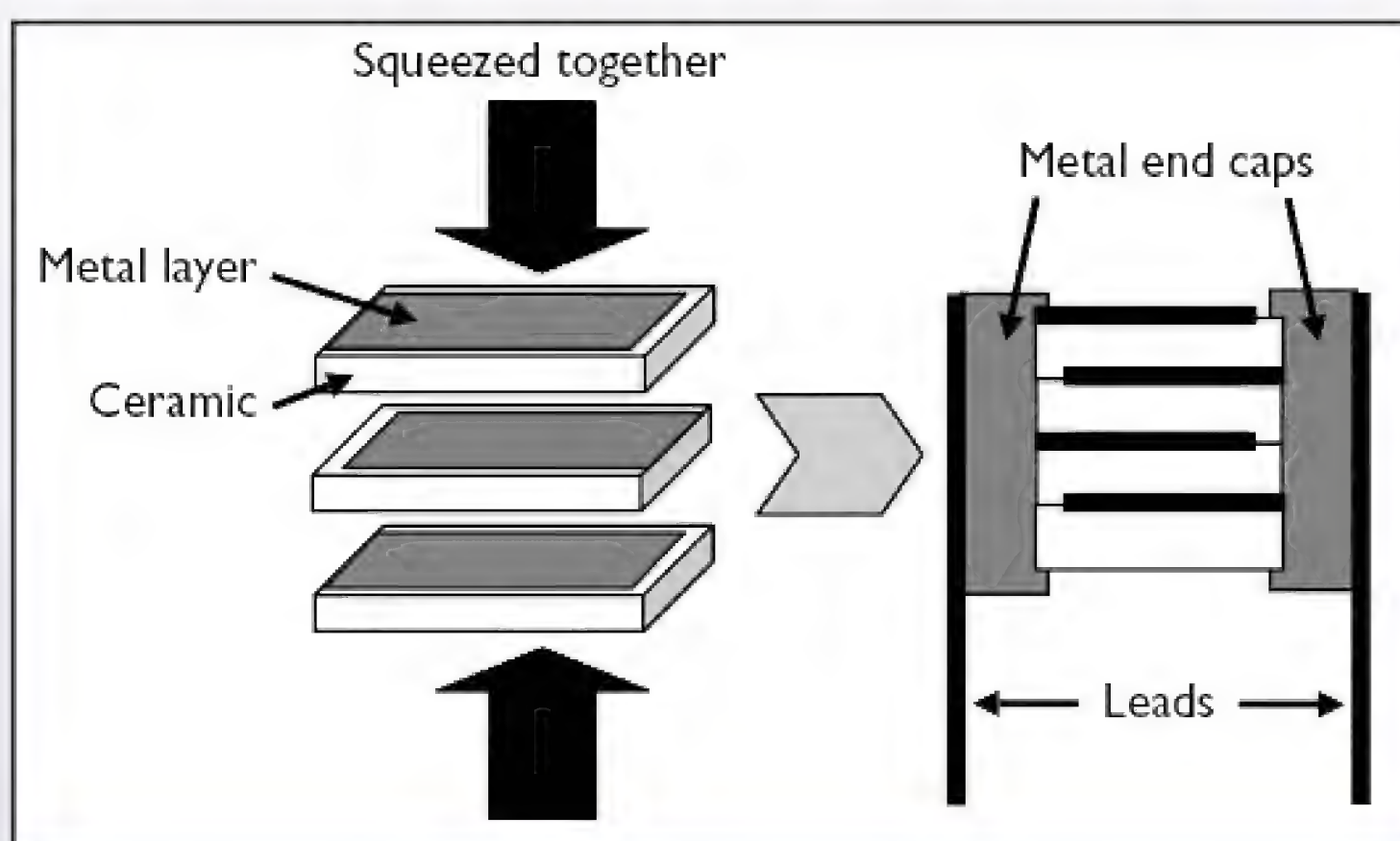


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## ■ CAPACITOR FUNDAMENTALS



**FIGURE 4.** Stack capacitors are made from an alternating stack of insulating and metallic layers.

Figure 4 shows a stack capacitor. The most common dielectric (as shown) is ceramic. Each piece of ceramic is coated with a thin metal layer on one side. The stack is oriented so that the metal layers only touch one side, alternating in each layer. The stack is then placed under pressure and heated (called sintering) to make a single solid piece of material. Metal end caps with leads are attached to each side of the stack, contacting the metal layers. The whole capacitor is then coated with an epoxy resin. The  $L_S$  of stack capacitors is very low.

### ELECTROLYTIC

The most common type of roll capacitor is the aluminum electrolytic. The dielectric is a porous layer of paper-like fiber, impregnated with a chemical gel that acts as a dielectric. Electrolytics have very high capacitance for their volume, but also have high  $L_P$  and  $R_S$  (lossy), and are relatively leaky (low  $R_P$ ). They can be made to

withstand substantial voltages. Electrolytics are polarized, meaning that voltage can only be applied in one way due to the chemical electrolyte. They generally have very broad tolerances of  $\pm 20\%$ .

### TANTALUM

Tantalum capacitors are a special type of capacitor. Instead of a roll of foil, an extremely porous "slug" of tantalum makes one electrode and an outer metal capsule the other. The dielectric is a chemical solution that forms an oxide coating on the tantalum slug for insulation. The slug has a tremendous amount of area, so capacitance is high, but  $R_S$  is also high (somewhat lossy). The short leads and small size of the capacitor means that tantalums have low  $L_S$ . The maximum applied voltage for tantalums is under 100 V. Like electrolytics, they are polarized and have broad tolerances of  $\pm 20\%$ .

### FILM

Film capacitors have a plastic film dielectric; polyethylene and polycarbonate are the most common. Most film capacitors are of roll construction, so  $L_S$  is moderate although stack types are not unknown. Film capacitors are non-polarized.  $R_P$  is high (low leakage) and  $R_S$  is low (low loss). Special types of film are used for highly stable capacitance values or extremely low leakage. Precision film capacitors of 5% tolerance or better are available. See [www.filmcapacitors.com/specsum.htm](http://www.filmcapacitors.com/specsum.htm) for a good table summarizing the different types of film capacitors.

### CERAMIC

By far the most common form of capacitor used, ceramic capacitors are used in high-frequency applications. Stack construction keeps  $L_S$  extremely low so they are useful at frequencies of hundreds of MHz. They are

## Choosing Capacitors

**N**ow that you know more about the types of capacitors, here is a list of common applications and the types of capacitors used in them. The reason that type is chosen is shown in parentheses.

- Power supply filtering (60 Hz) — electrolytic (high value, low cost)
- Switching power supply filtering — electrolytics with low ESR and low ESL, film (high frequency current handling)
- Power bus filtering — tantalum and electrolytic (good medium and high-frequency characteristics)
- Digital IC bypassing — ceramic (excellent high frequency characteristics)

- Timers and oscillators — polystyrene film or NP0 ceramic (stability and precision)
- Audio filters and amplifiers — film (low-loss and small)
- Analog-to-digital conversion — low-leakage film (stability and precision)
- RF filters — silvered-mica, air variable, or transmitting ceramic (low-loss and stable)

The important thing to remember in order to make the correct capacitor choice is to think about what is important for your circuit — value, stability, cost, loss — and choose a capacitor type that meets those requirements.



## ■ CAPACITOR FUNDAMENTALS

low-loss (low  $R_S$ ) and have good leakage characteristics (moderate  $R_P$ ). Ceramic capacitors are very rugged and pack a lot of capacitance into a small package. Ceramics are non-polarized and have a wide range of tolerances.

### MICA AND GLASS

You will occasionally find silvered-mica and glass capacitors in RF and transmitting equipment due to their extremely low loss (low  $R_S$  and high  $R_P$ ) and low  $L_S$ . A variation on the ceramic stack, mica and glass dielectric layers are used instead of ceramic. They cannot be sintered like ceramic, so this limits the capacitance that can be obtained. Both types typically have a 5% tolerance.

### ADJUSTABLE

If you take apart an old radio, behind the tuning knob you'll see an air-variable capacitor with closely-spaced metal plates. While these are typically small in value (1,000 pF or less), they are adjustable. Air variables are stable and low-loss, working very well at RF. An adjustable variation of the mica capacitor in which the stack is squeezed by a screw is called a compression trimmer. Ceramic and plastic variables are also available with values of up to several hundred pF. **NV**

## About the Author

**H.** Ward Silver is an engineer, writer, and teacher with over 30 years of practical experience in medical electronics, instrumentation design, and broadcasting. He is the author of *Ham Radio for Dummies* by Wiley Press and numerous articles for *QST Magazine*. Ward's ham radio call sign is **NØAX**.

## For Further Reading

**B**y now, you're aware that there's a lot more to a capacitor than its capacitance. To learn more, browse the Capacitor Term Glossary at [www.capacitorindustries.com/glossary.htm](http://www.capacitorindustries.com/glossary.htm). The information at <http://xtronics.com/kits/ccode.htm> will help you decipher capacitor value markings. A whole web page full of links about capacitors can be found at [www.hallbar.com/capacitors.html](http://www.hallbar.com/capacitors.html). If you are really interested and can find a copy, *The Capacitor Handbook* by Kaiser (CJ Publishing, 2851 W. 127th St., Olathe, KS 66061) is an authoritative, but easy-to-read reference.

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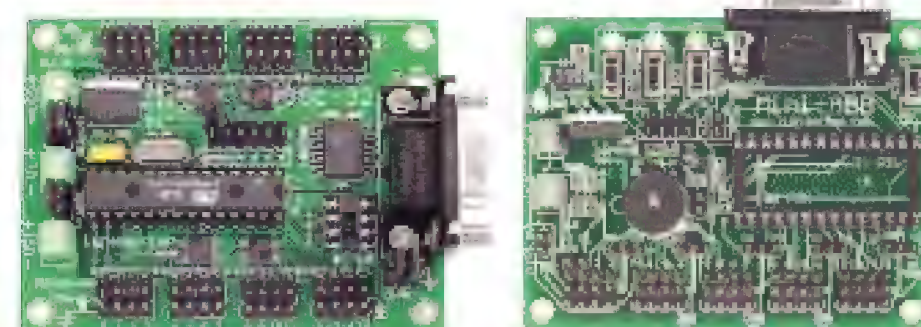
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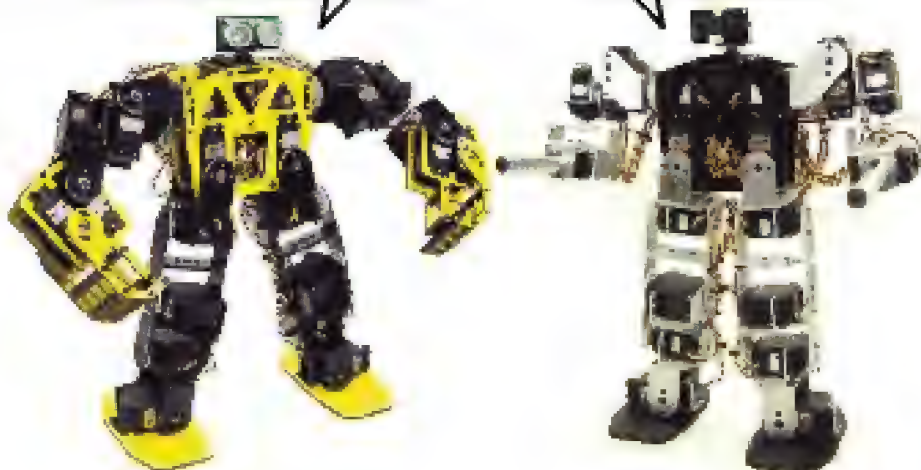


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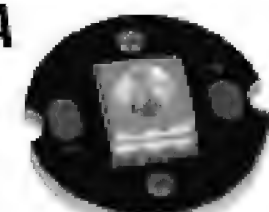


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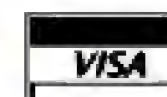
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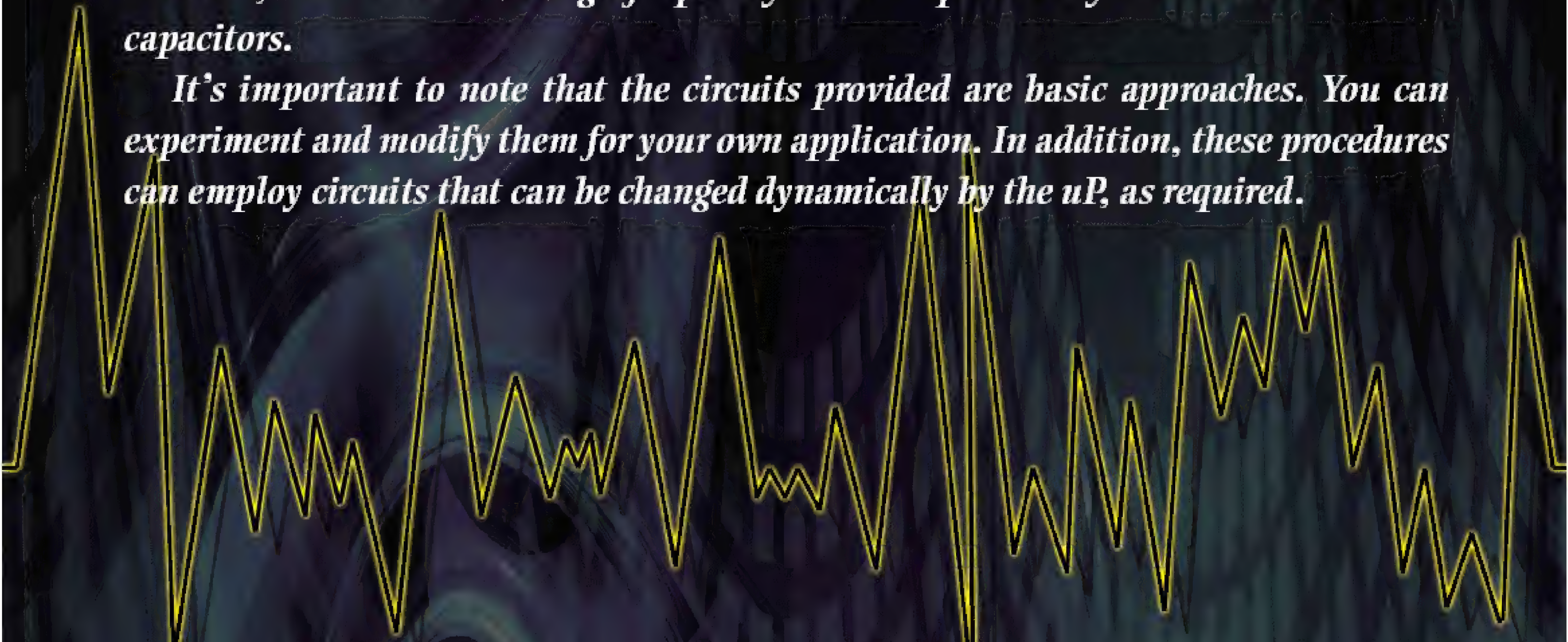
# — Generating ANALOG WAVES — From DIGITAL SIGNALS

by Gerard Fonte

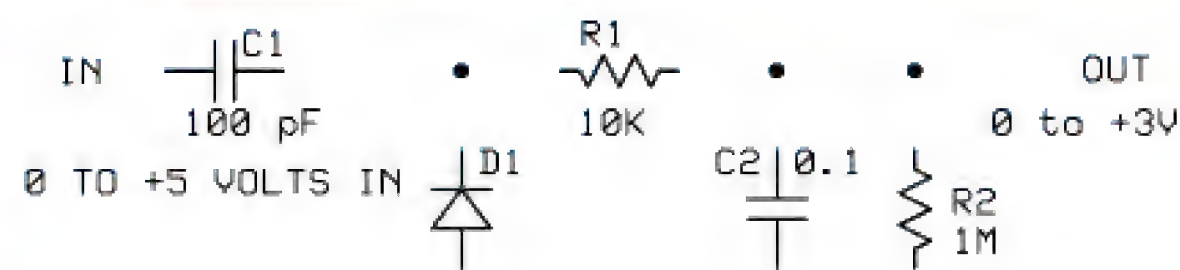
**F**rom the digital designer's perspective, it's unfortunate that the real world is analog. While many low-cost microprocessors (uP) have A/D (Analog-to-Digital) inputs, I am not aware of any common and inexpensive uPs that have real D/A (Digital-to-Analog) outputs, although the Microchip PIC 1400 does have two crude 4-5 bit analog outputs. Naturally, this shortcoming is sorely missed when creating any type of analog control application, as well as many other applications.

There are two different means of simply and easily generating quality analog signals from digital signals. One method generates DC and low frequency (a few Hz) analog outputs. The other creates AC signals into the high audio-frequency range. Both methods can provide up to 10 or more bits of resolution and noise that's 60 dB or more below full-scale. The DC/low frequency approach uses two capacitors, two resistors, and a diode. The high-frequency circuit requires only two resistors and two capacitors.

It's important to note that the circuits provided are basic approaches. You can experiment and modify them for your own application. In addition, these procedures can employ circuits that can be changed dynamically by the uP, as required.







**FIGURE 1.** BASIC CIRCUIT FOR DC AND LOW FREQUENCY SIGNALS. NOTE THAT R2 CAN BE ELIMINATED IF THE SUBSEQUENT CIRCUIT HAS A SIMILAR RESISTANCE TO GROUND.

Test Frequency	Original Measurement	Second Measurement	Percent Difference
100,090 Hz	2.9036 volts	2.9033 volts	+0.01% (~13 bits)
10,008 Hz	1.5964 volts	1.5952 volts	+0.07% (~10 bits)
4,000 Hz	0.9098 volts	0.9091 volts	+0.07% (~10 bits)
1,003 Hz	0.2903 volts	0.2903 volts	0.0%
100 Hz	0.0301 volts	0.0300 volts	0.0% (+/-1 digital error)

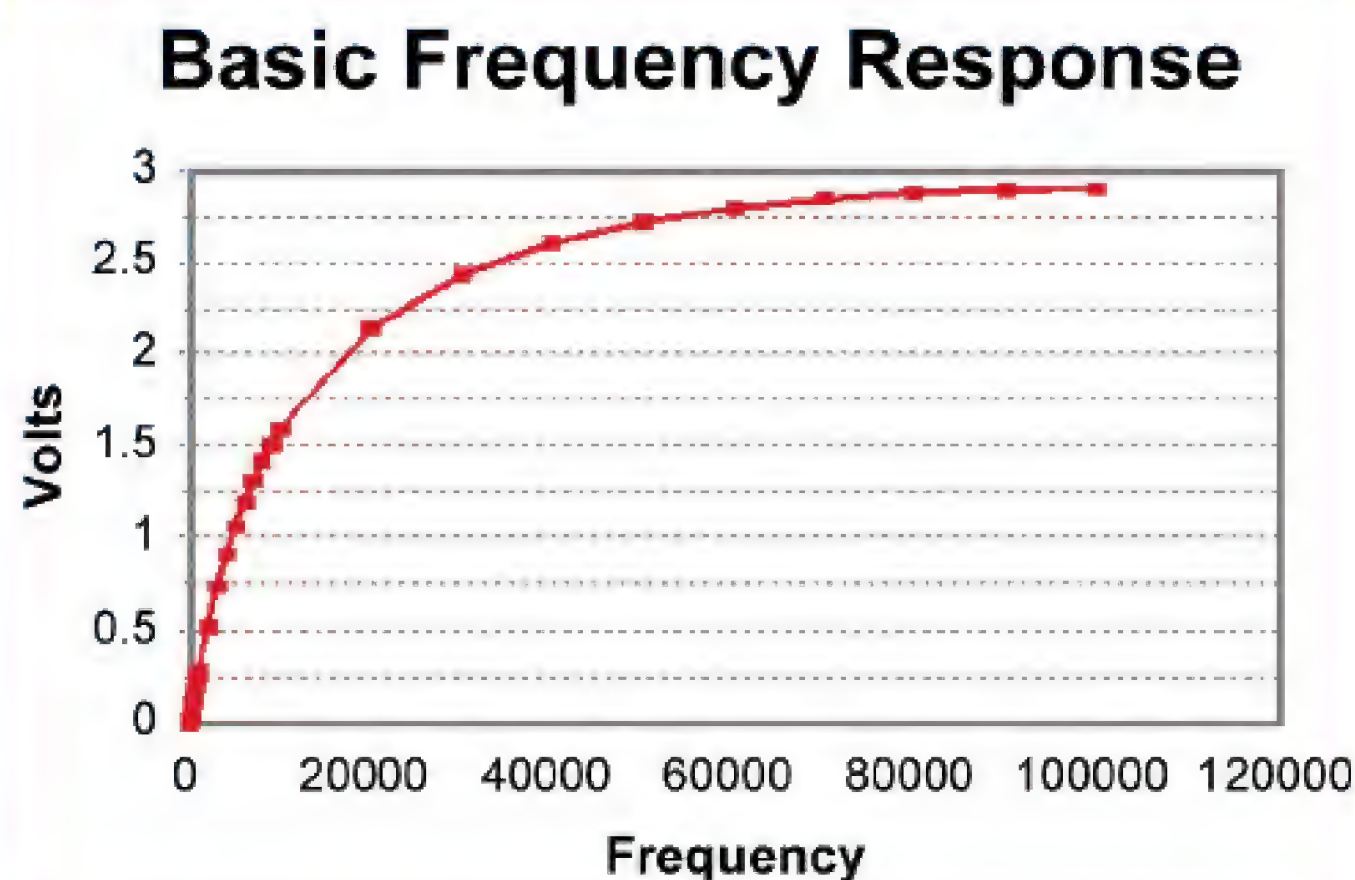
**TABLE 1.** THE REPEATABILITY OF THE OUTPUT VOLTAGE IS VERY GOOD.

## DC and Low Frequency Converter

In the DC and low frequency converter (see Figure 1), the first circuit converts a series of repetitive digital pulses (typically a square wave) into a DC signal. By changing the digital frequency, the DC signal can be changed, which allows low frequency AC signals to be created. For the circuit shown, the maximum useable frequency is about 10 Hz, though you could probably modify the circuit to get up to 60 Hz. This is basically a frequency-to-voltage converter.

The operation of the circuit is straightforward. The

**GRAPH 1.** THE OUTPUT VOLTAGE HAS A NON-LINEAR RESPONSE RELATIVE TO THE INPUT FREQUENCY. THIS MAKES OUTPUTTING A SPECIFIC VOLTAGE TRICKY.



capacitor C1 has two effects. It blocks DC and creates pulses at each edge of the digital input. The diode shorts the negative pulses to ground, which leaves a short positive pulse of about 2  $\mu$ s for each rising edge of the input.

These high-frequency pulses are filtered and averaged by the RC network of R1 and C2 to create a DC signal. Resistor R2 is used to load C2. It should be a high value of about 1 to 10 M $\Omega$ , so that there is little reduction of the output voltage. It is required, however, because there is no way to remove a DC voltage on C2 once it's there. If you want a peak-hold circuit, eliminate R2. The resistor R2 can also be eliminated if your subsequent circuit, which connects to the output, has a similar load to ground. Note that Figure 1 is a starting point that seems to work well for input frequencies of 1 KHz to 100 KHz. You may want to experiment with different values for your particular application.

## How Well Does it Work?

I measured the DC output with a 1 M $\Omega$  oscilloscope probe in place of R2, and was able to get out about 0.0 volts to +3.0 volts. I say "about" 0.0 volts because that value is asymptotic. You can never get there if there is any digital signal coming in. I went down to 10 Hz and was able to measure 0.0027 volts with my 5.5 digit voltmeter. At 100,000 Hz (my highest test frequency), I measured 2.9036 volts, though you might get more voltage with a higher frequency. This is about 60% of the 5 volt operating voltage. Assuming that 0.0027 is the smallest step possible, then there are 1,075 of these steps in 2.9036 volts. This corresponds to a D/A with 10 bits of resolution. I tried ceramic, mica, and polyester capacitors and I didn't see any significant difference.

I measured the noise with an oscilloscope. At 100 KHz, the noise was about 4 mV peak-to-peak (P-P). The P-P noise at 10 Hz was about 8 mV. (Please note that I discounted 60 Hz power-supply noise that was also present. Also, because the noise is AC and must eventually sum to zero, the DC voltage measured with the meter can be less than the AC noise. The DC meter reads a value over time, so the AC noise tends to zero itself out.) With 4 mV of noise and a 2.9036-volt signal, the signal-to-noise ratio (S/N) is 726. This is a conservative measurement because proper noise measurement should be RMS (Root-Mean-Square) not P-P. Converting P-P noise to RMS is complex and is beyond the scope of this article. But an RMS value is always less than a P-P value. So, let's estimate the S/N ratio as 1,000. This corresponds to 60 dB or about 10 bits.

A crucial requirement of any conversion circuit is its repeatability. As shown in Table 1, the repeatability is very good. It should be noted that these tests used an inexpensive RC (Resistor/Capacitor) oscillator, rather than a  $\mu$ C with a crystal oscillator. So, some of the repeatability



error may be due to the instability of the RC frequency. Approximately 30 minutes elapsed between the first and second measurements.

The frequency response, unfortunately, is highly non-linear (see Graph 1). This may not be a problem if your design is a closed-loop. In this case, you simply increment or decrement the voltage until a proper response is obtained. However, if you want to output a particular voltage, say 2.52 volts, it's not effortless.

The crude way to obtain frequency response is to build a look-up table based on values you actually measure on a breadboard. But this is problematic, as resistors and, especially, capacitors have values that vary by several percentage points. So, there will be differences in the output voltage from unit to unit. You could tailor your uC by inputting specific values during program loading for specific components, but this is cumbersome. A better way is to use the built-in A/D that most uCs have.

During start-up or self-test (a self-test routine is crucial), you could measure the actual voltage with known applied frequencies and build a look-up table automatically. This limits the resolution to the available A/D resolution, but this may be adequate for many applications. Most uC A/D converters specify a 10K or less analog signal impedance. This is not a problem because C2 is very large relative to the A/D capacitor.

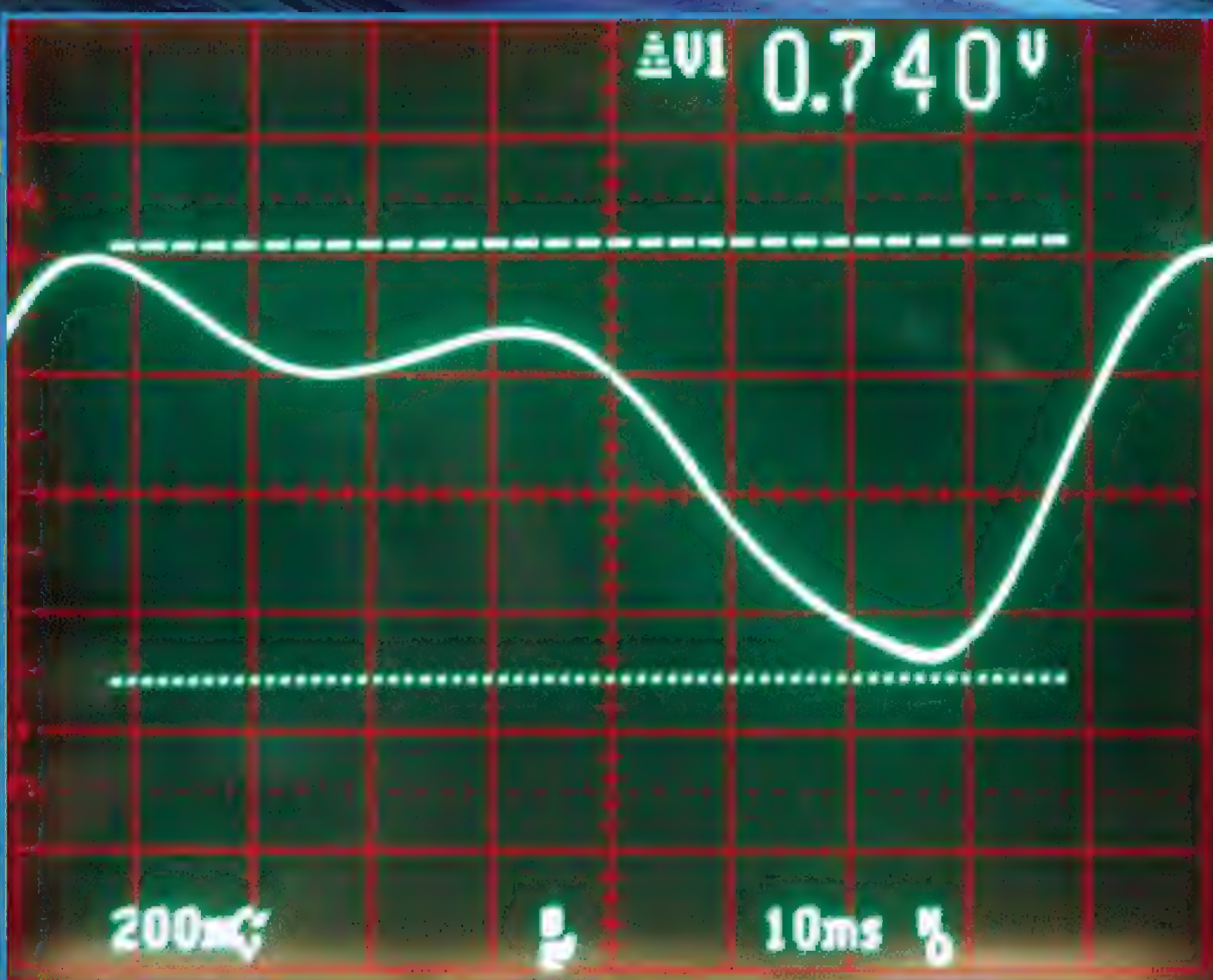
Your look-up table will probably contain about 20-40 entries, and you will interpolate between the values. This procedure reduces the memory requirements and usually provides adequate results. When you do this, you are really converting the curve to 20-40 straight-line segments. Generally, the difference between the curve and the straight line are minimal. Of course you can, and should, calculate the difference to be sure it is suitable for your application.

## Frequency Modulation

DC voltages are nice, but nothing is fixed. Naturally, you'll want to change it from time to time. The question is how quickly the DC level can change. I breadboarded a quick and dirty modulator that swept the frequency from 3,400 Hz to 175 KHz. It was supposed to be a sine wave, but if you look at Photo 1 you'll see that the falling edge has a ledge in it. The FM frequency was about 10 Hz and the resultant signal amplitude was about 0.75 volts. You can change the values of the resistors and C2 to change the response of the circuit. You can probably get up to a useful frequency of 60 Hz, but I wouldn't expect to go much higher.

## Variations on a Theme

By changing the circuit slightly, different output voltages can be obtained. If the diode is reversed, a negative

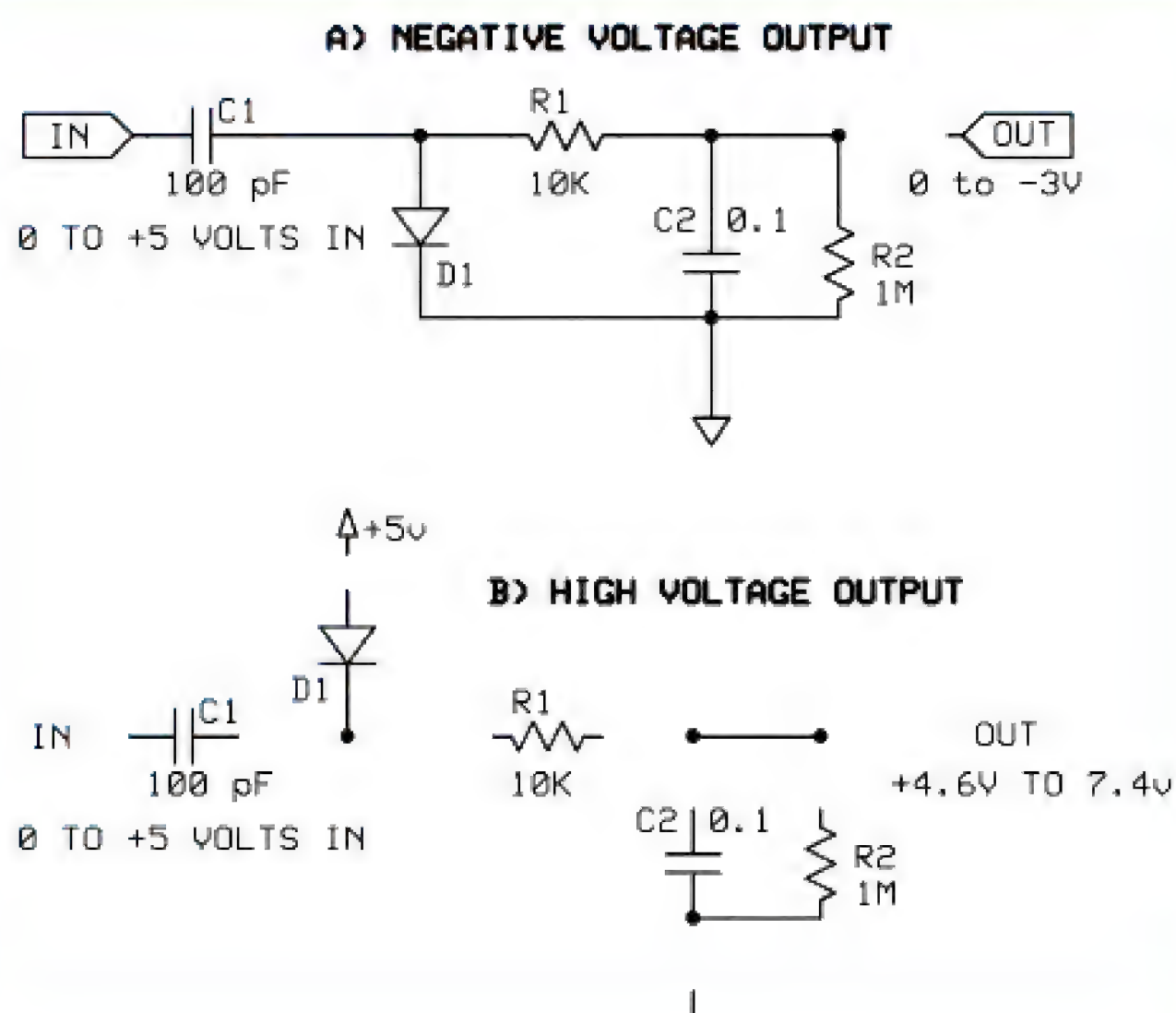


**PHOTO 1.** A POOR ATTEMPT AT AN FM SINE WAVE. HOWEVER, THE SIGNAL IS NICE AND CLEAN WITH NO TRACE OF DIGITAL NOISE.

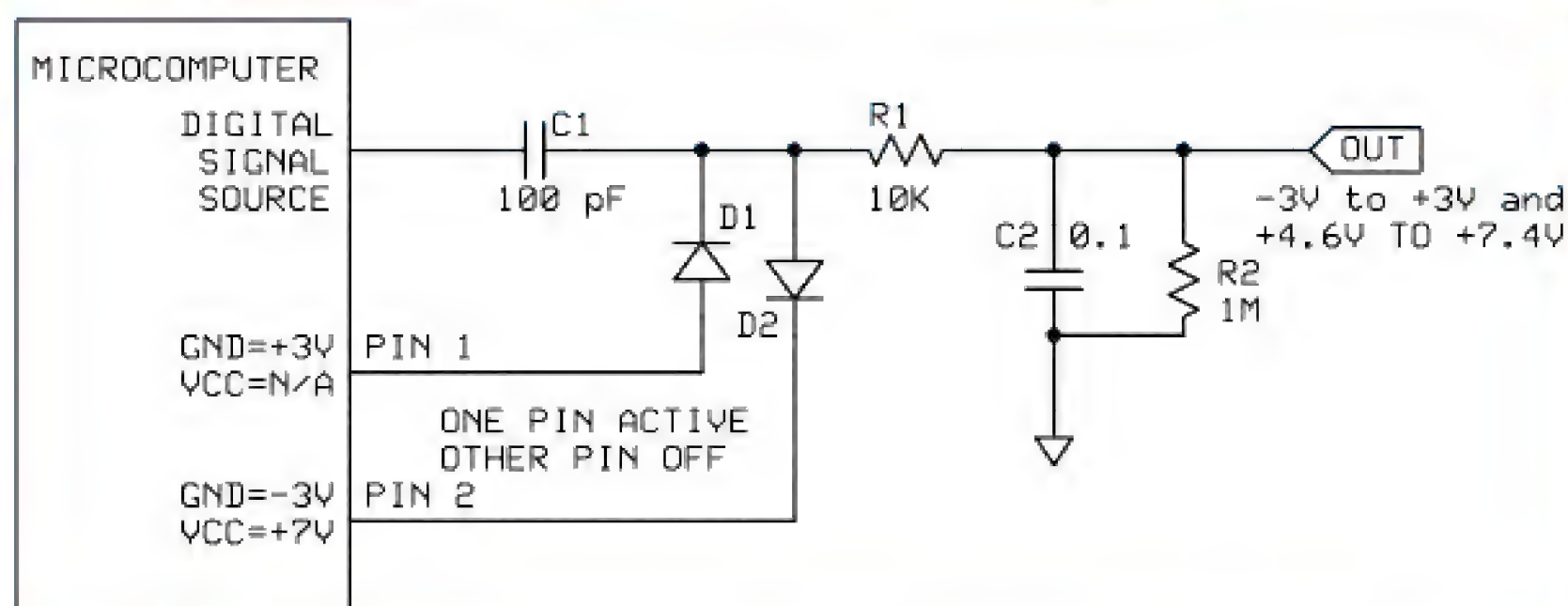
voltage is created (Figure 2a). If the diode's anode is connected to a positive voltage (typically VCC or +5 volts) the output voltage can be about 50% greater than that (Figure 2b). This gives you great flexibility and is something that ordinary D/A converters cannot accomplish. You can output any voltage from -3 to +3 volts and from +4.5 to +7.5 volts with a standard 5-volt power supply. (There may also be enough current to supply the negative voltage requirements for an op-amp or two.)

These circuits will work with any digital input. However, if you are using a uC, you can select whatever output you desire. All that is needed are a couple of free I/O pins and another diode. Figure 3 illustrates how this can be done. The key concept is to realize that an output pin in a high-

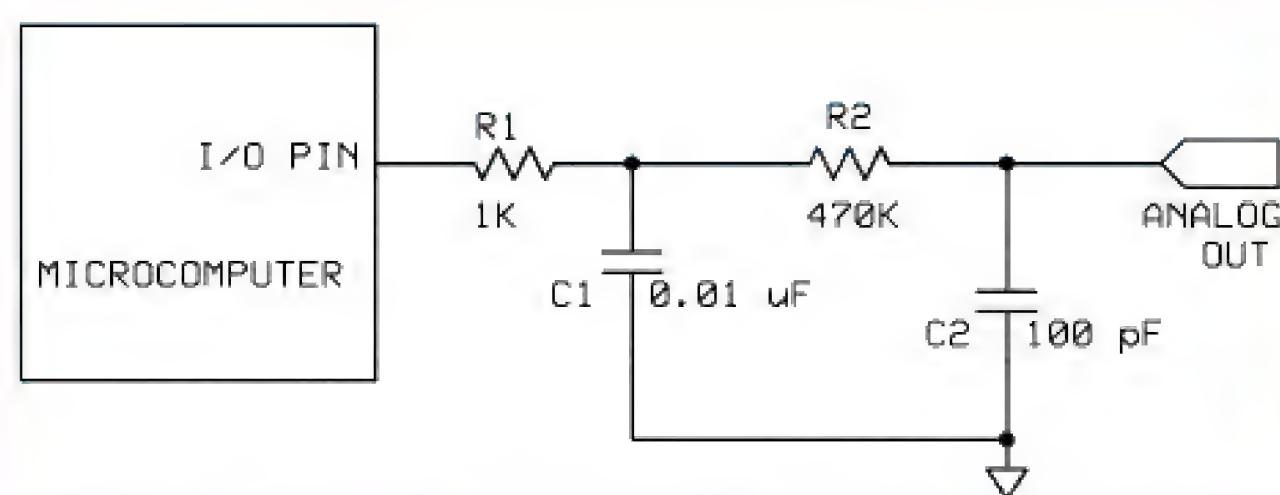
**FIGURE 2.** BY CHANGING THE DIODE CONNECTIONS, DIFFERENT OUTPUT VOLTAGES CAN BE GENERATED.







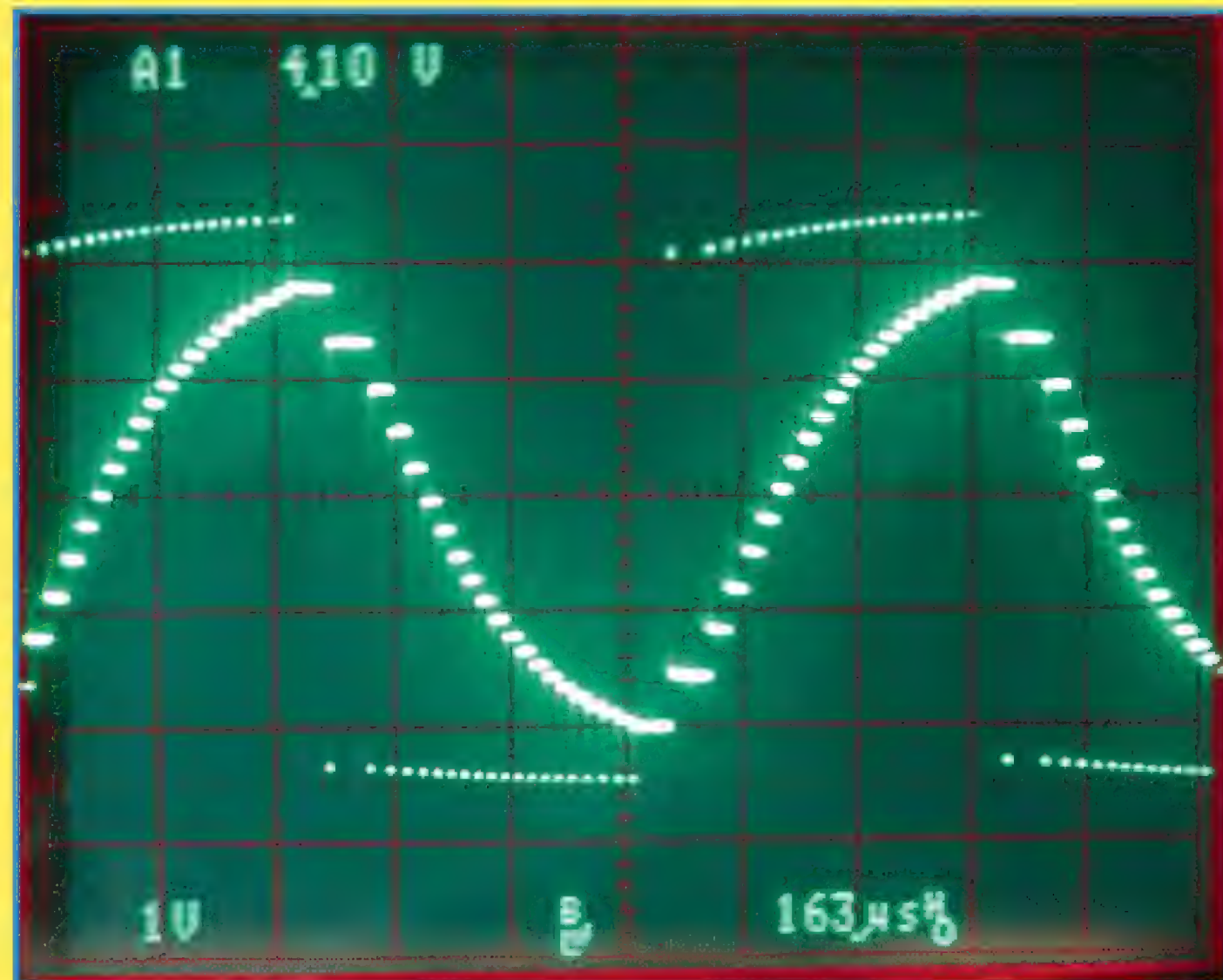
**FIGURE 3.** YOU CAN TRI-STATE UC PINS TO EFFECTIVELY CONNECT/DISCONNECT CIRCUIT COMPONENTS. IN THIS WAY, YOU CAN CHOOSE WHAT OUTPUT VOLTAGE YOU WANT ON THE FLY.



**FIGURE 4.** BASIC CIRCUIT FOR HIGH-FREQUENCY SIGNAL GENERATION. IT'S A STEP-HOLD CIRCUIT FOLLOWED BY A SMOOTHING FILTER TO ELIMINATE THE STEPS.

impedance state is effectively disconnected from the circuit. So, if you want 0 to +3 volts, drive pin 1 low and set pin 2 to a high-impedance state. If you want 0 to -3 volts, drive pin 2 low and set pin 1 to the high-impedance state. For +4.5 volts to +7.5 volts, drive pin 2 high with pin 1 disconnected.

**PHOTO 2.** A PICTURE OF A STEP-HOLD SIGNAL TAKEN AT THE UC PIN (BEFORE FILTERING). THE SMALL PULSES CAUSE THE STEPS, AND THE TERRACES ARE THE CAPACITOR HOLDING THE VOLTAGE. ANOTHER POOR ATTEMPT AT A SINE WAVE.



The 1.5-volt dead zone between +3 volts and +4.5 volts is annoying. However, it seems that if you applied a digital signal, instead of a steady state, to pin 2, you should be able to adjust the output voltage. This is because this output would be oscillating between a positive voltage and a negative one. The capacitor C2 should average/filter this out to a DC value. By adjusting the duty cycle, you should be able to adjust the voltage, although I haven't tried this. Additionally, you will be

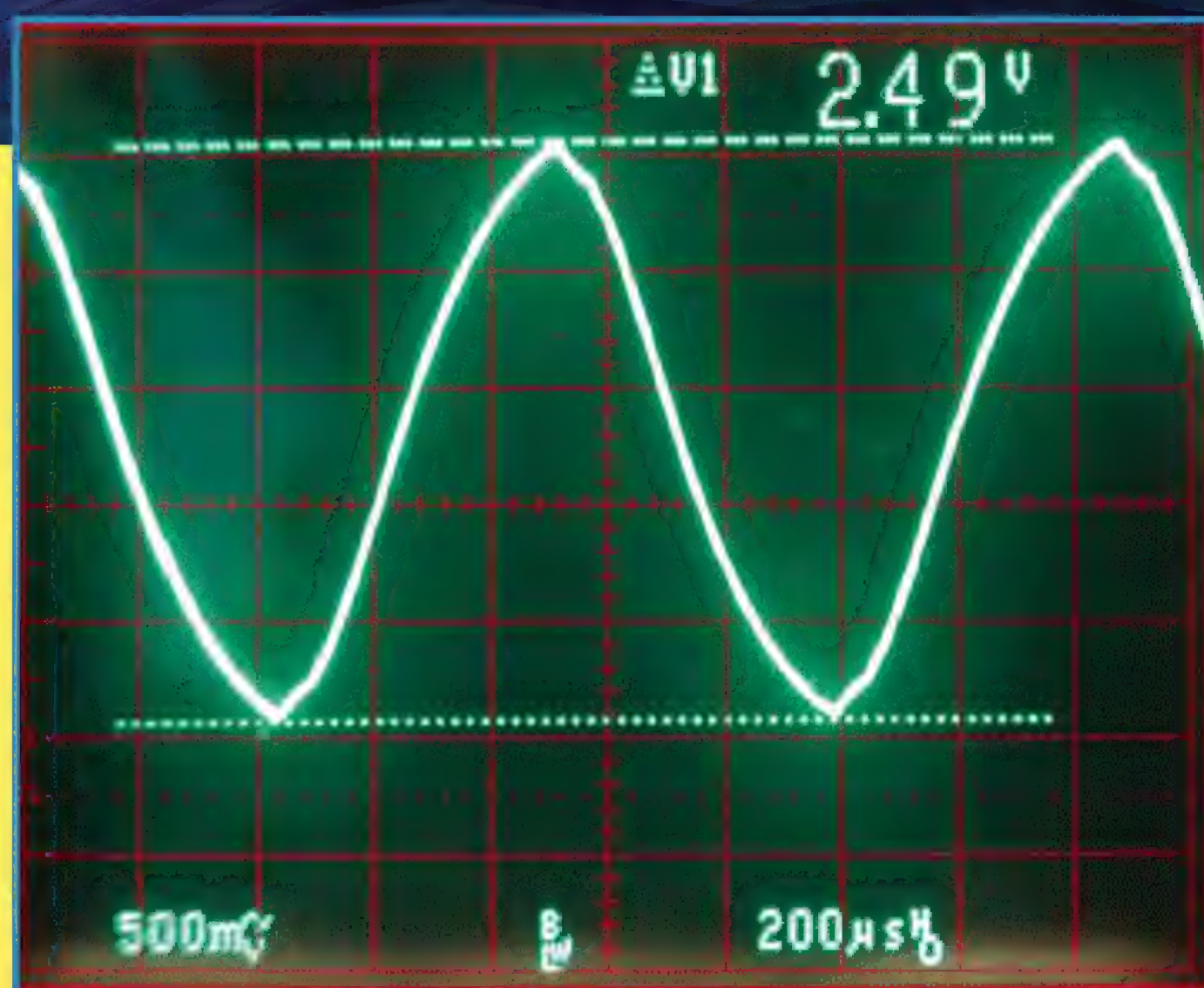
combining two voltages: one from the input pin and one from pin 2. This combination is probably not linear. Lastly, the frequency applied to pin 2 must be chosen properly or else it could beat/heterodyne with the frequency at the input pin and cause problems at the output. On the other hand, this might actually be a useful method of creating sine waves, but it's not a method I've tried. There are many elements with which to experiment.

## High Frequency Output

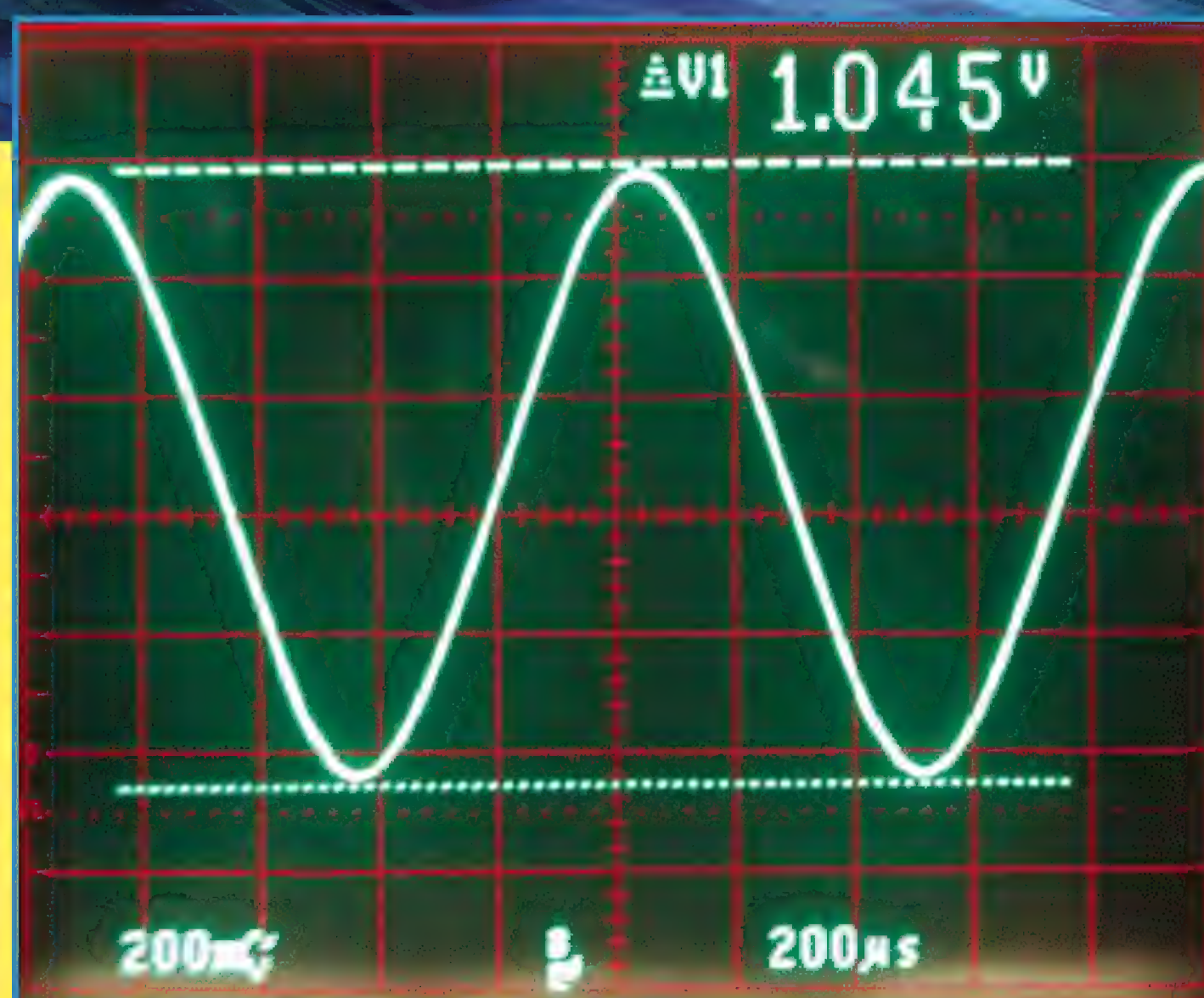
The second approach is completely different and a bit more subtle (see Figure 4). The key aspect to this approach is that the uC pin is disconnected from the circuit when in the high impedance state. Here's how it works: The I/O pin is set to output and driven high or low for a very short time. (I used a PIC uC and a 4 MHz crystal, so these pulses were 1 uS in length.) Then it is turned "off" by making it an "input" pin with high impedance (see Photo 2). These pulses are current-limited by R1. They pass through R1 and are applied to C1. Because these pulses are so short, relative to the time constant of R1/C1, the capacitor gets only a step charge or discharge. When the I/O pin is off, the capacitor holds the value. So, by proper stepping and holding, you can create any waveform you like (to a degree). We have an arbitrary waveform generator.

Let's look closely at Photo 2, which is measurement at the I/O pin. The very short pulses that are near +5 volts and ground are the step pulses, when the pin is set as an output pin and driven either high or low. The relatively long terraces are the hold values when the pin is set as an input. Note that the steps are not a constant height. This is because more current will flow when there is a higher voltage difference. So, a down-step when the hold voltage is near +5 volts is much larger than a down-step when the hold voltage is near ground. You will also notice that there is a droop in the actual step voltages because of the load on the pin. In the worst case, positive step voltage sags by almost 0.5 volts. The ground step voltage rises to about 0.15 volts in the worst case. This indicates that the pin can sink current better than it can source it.





**PHOTO 3.** EVEN WITH THE POOR STARTING SIGNAL, THE FILTER MAKES THE SIGNAL LOOK REASONABLE. AGAIN, NOTE THE LACK OF DIGITAL NOISE.



**PHOTO 4.** INCREASING THE FILTER CAPACITOR MAKES THE SINE WAVE BETTER AT THE EXPENSE OF AMPLITUDE.

You will note that there are different lengths of time between some of the step pulses. I was trying to make a 1,000 Hz sine wave out of 40 steps. As you can see, it's not very good. The problem is the varying step size, but we'll come back to that later. Right now, let's examine the last two components of the circuit: C2 and R2. These two parts make a low-pass filter to remove the step pulses and smooth the waveform. Photo 3 shows what the output looks like after it's been filtered. Considering the input, it's not too bad. There are 2.5 volts of a 1 KHz sine wave that has 5.6% distortion. By changing C2 to 1,000 pF, the distortion drops to 1.25% with 1.0 volts of amplitude (see Photo 4). This looks much better. Photo 5 shows the spectrum of the signal. You can see that the third harmonic is larger than the second harmonic. This is because of the poor starting waveform.

## Considerations


The more steps there are in the waveform, the easier it is to filter them out. I chose 40 steps because that created a very clean signal after the filter. The PIC was running at 4 MHz and was almost completely occupied with creating the waveform. The maximum speed for some PIC uCs is 40 MHz, which means that the highest frequency waveform that can be created with 40 steps is 10,000 Hz.

SEPTEMBER 2005

Unfortunately, the control registers for the I/O control of the pin are on a different page from the drive control registers. This means there is a lot of time/cycles lost in switching back and forth between pages. There are other low-cost uC manufacturers that have all the I/O registers


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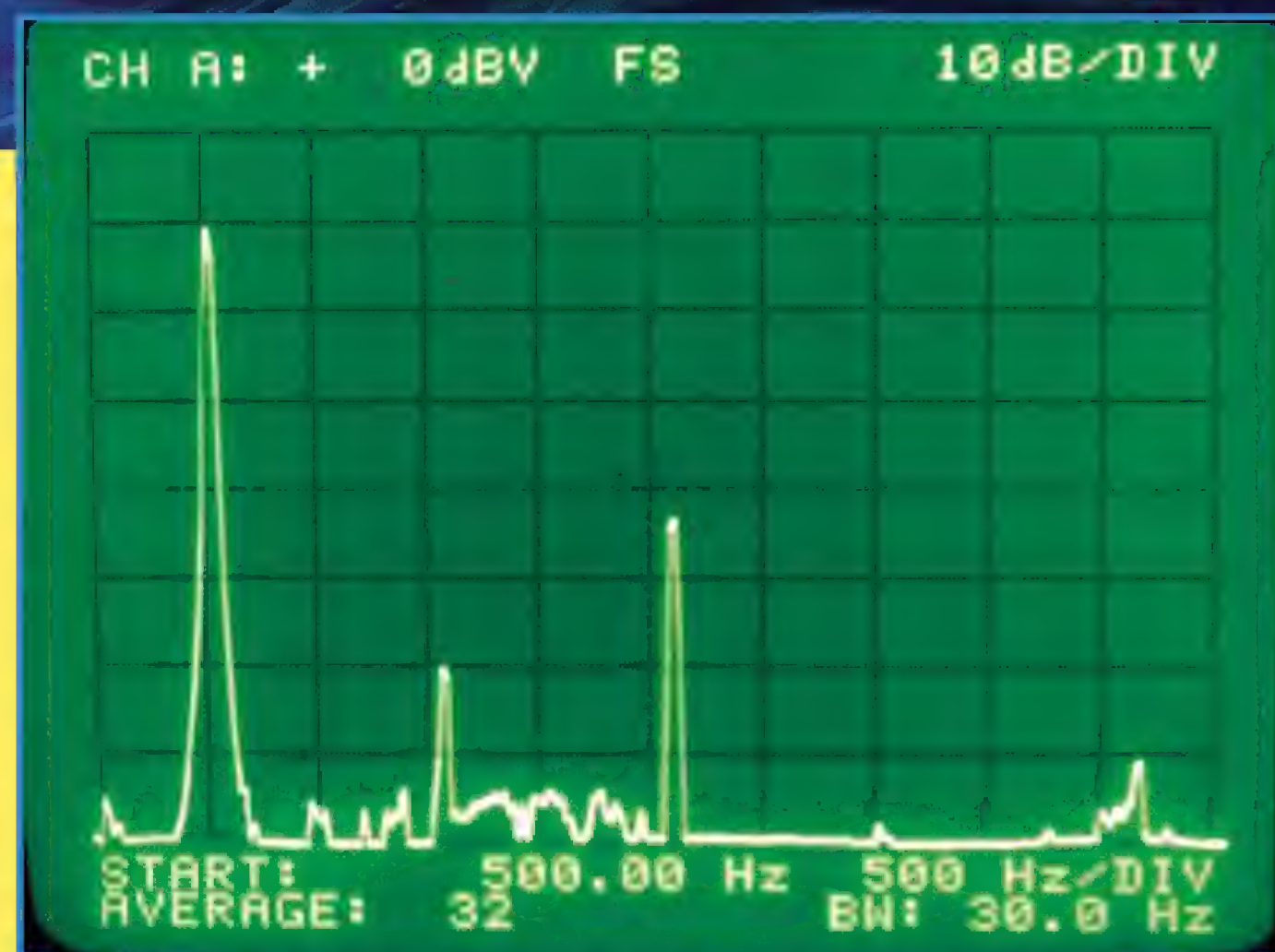
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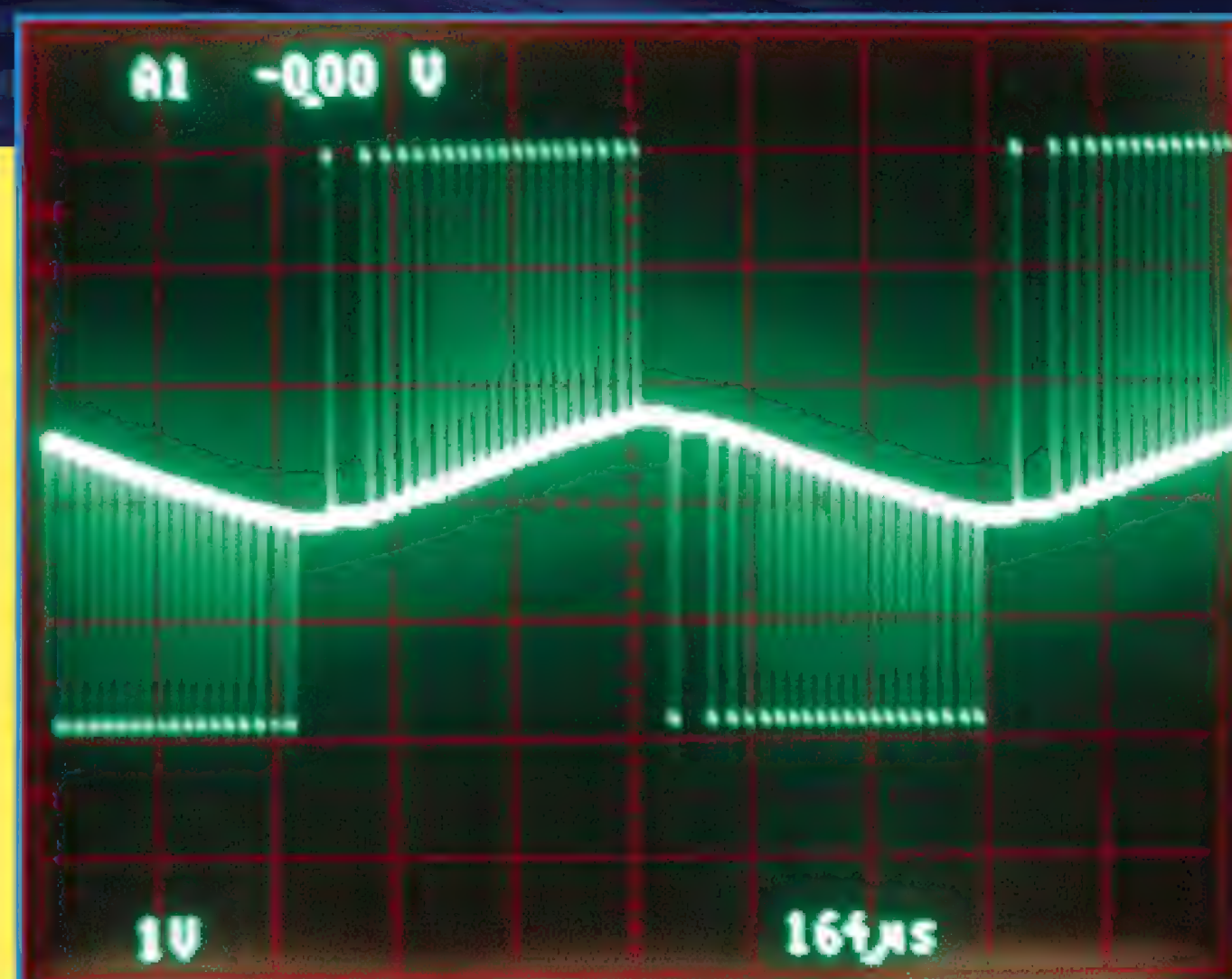
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**PHOTO 5.** THE SPECTRUM OF THE SIGNAL IN PHOTO 4 SHOWS THAT THE THIRD HARMONIC IS ABOUT 32 DB DOWN. AGAIN, CONSIDERING THE INITIAL WAVE SHAPE, IT'S NOT TOO BAD. NO HIGHER FREQUENCY HARMONICS WERE SEEN BEYOND THE FIFTH (JUST VISIBLE AT -60 DB).



**PHOTO 6.** USING A 10K RESISTOR FOR R1 INSTEAD OF 1K RESULTS IN SMALL STEPS. BY CHOOSING LARGE OR SMALL STEPS, THE PROBLEM OF INCONSISTENT STEP SIZE CAN BE ADDRESSED.

on the same page, but the ones I saw had clock speeds in the single digits, so they will be slower.

You will note that I used a large resistor and small capacitor in the filter circuit (R2 and C2). I did this to reduce the load on the circuit as much as possible. Smaller resistors and larger capacitors can have the same frequency response, but the loading effect will be greater. This circuit also has a high-impedance output and is sensitive to loading.

The differing step sizes do have a convenient property. An equal number of up-steps and down-steps will always result in a wave that is centered at  $1/2 V_{CC}$ . That is, it has a DC level of  $1/2 V_{CC}$ . This is because the steps always get smaller as you move away from that point on any generated waveform (in sequence). If this was not the case, the DC level could shift and the wave could bump into the high or low voltage limit. This would result in a flat spot, or clipping of the signal.

## Making it Better

You can change the step sizes by changing R1, because R1 controls the amount of current into C1. If you

make R1 larger, the steps are smaller, and vice-versa. Photo 6 shows that the steps get much smaller and more consistent when R1 is increased to 10K. However, the wave is smaller in amplitude. This means more steps for a larger amplitude, which results in a lower maximum frequency. What we really need is some way of changing the current steps at will. In this way, we can use low current steps when there is a large voltage difference and large current steps when there is a small voltage difference.

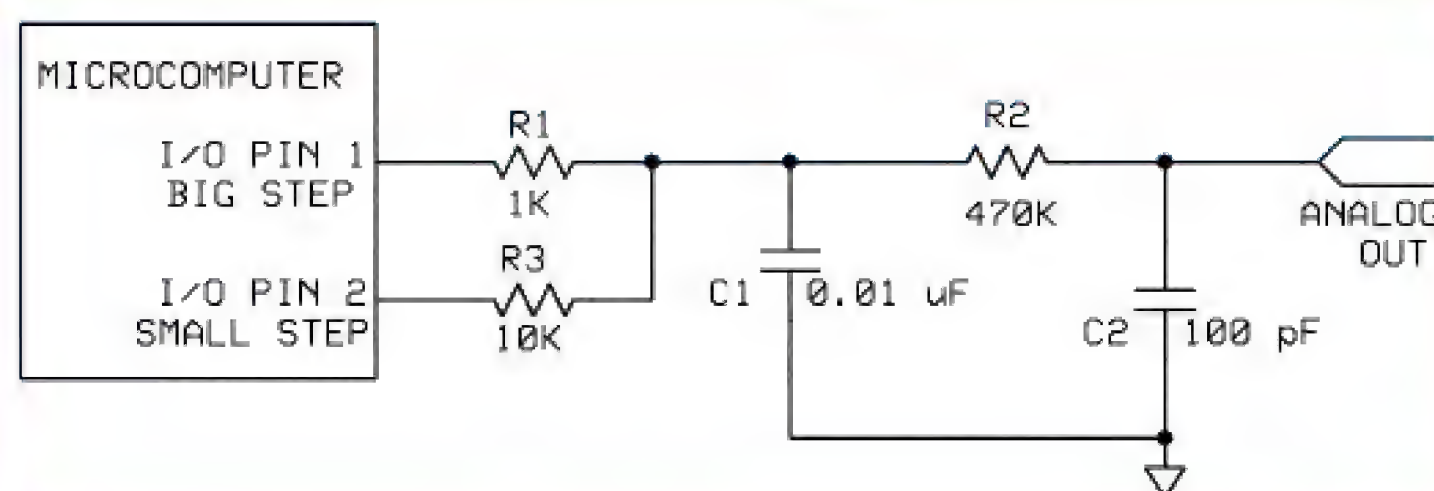
Figure 5 shows how this can be done. As before, only one pin is on at a time. The other one is set to a high-impedance state. By selecting which pin is driving the circuit, you can choose the size of the step. Of course, you can use as many different step sizes as you like. This means that the waveform can be defined as precisely as you like. The better defined the waveform, the less distortion there is.

With low frequency signals, C1 may start to discharge or droop due to internal leakage. This can be reduced with a good quality capacitor. Alternatively, you could switch a larger-value capacitor into the circuit.

## Conclusion

Getting good analog signals out of digital ones can be done fairly easily with a minimum of parts. It does take some programming effort, and high-frequency audio signals require most of the uC clock cycles. However, the two general approaches described have a number of very useful characteristics. Additionally, the procedure that allows components to be switched in and out of your circuit permits you to dynamically change your circuit as required. If you experiment with these methods, you will probably find more interesting applications for your projects and products. **NV**

**FIGURE 5.** HIGH-FREQUENCY CIRCUIT WITH BIG AND SMALL STEPS. THIS HELPS COMPENSATE FOR THE INCONSISTENT STEP-SIZE OF THE BASIC CIRCUIT.





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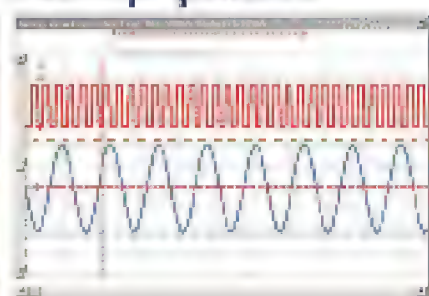
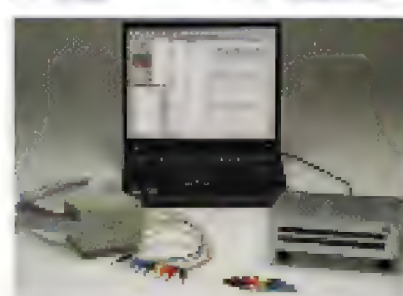


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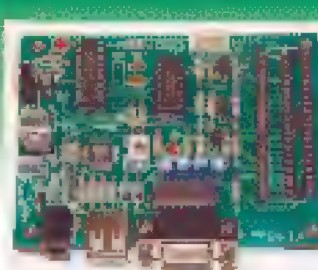
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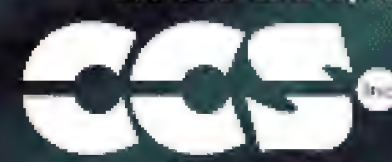
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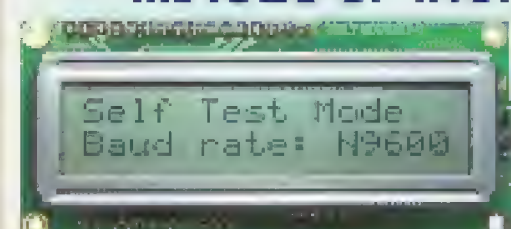
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Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

# Stamp Applications

## How to Use a Terminal Program and an SX for Control

*Well, it's good to be home. Since the start of the EFX group, my colleague, John Barrowman, and I have been doing a lot of traveling and participating in group events, many having to do with Halloween and holiday decorating. It's interesting what folks will ask for, some of it odd, some of it quite straightforward. After the MIDI project we did with the SX28 a few months ago, I got a lot of mail asking how to use a terminal program and an SX for device control. We can do that — and with some recent updates to the SX/B compiler, it's even easier to do.*

I have to admit that I'm having an absolute blast with the SX/B compiler. That may seem silly, especially since I'm "on the inside" and am actually part of the development team. Still, I'm really having fun. SX/B is letting me build high-performance projects — both for work (several Parallax EFX products, for example) and for play — with relative ease. And when one needs to build lots of do-dads, the low cost of the SX controller line is certainly a big help.

I feel like my greatest strength for the SX/B team is that I come from the ranks of BASIC Stamp users. Like many of you, I'm just not patient enough to write full-blown assembly language programs (and I have tremendous admiration for those who do). What I like about SX/B is that I can get full performance from the SX without having to go the assembly language route. I frequently send a note to our compiler engineer that says, "Hey, I'd like to do this ..." He's a pretty accommodating guy and, with input from me and other devoted users, SX/B continues to grow.

At press time, the latest version of SX/B is 1.4, and it offers a couple of really nice new features that we'll exploit this month in our project. The first is the ability to allow a subroutine to return a value to the caller without having to explicitly declare the destination address in the call. We

used to do this:

```
RX_BYTE @char
```

Now we can do this:

```
char = RX_BYTE
```

Why does this matter? Well, the latter version is easier to understand and we don't have to remember to add the pesky "@" (address of) symbol. It actually simplifies the subroutine code, as well. Prior to version 1.3 (when return values were introduced), we would write the RX\_BYTE subroutine like this:

```
RX_BYTE:
  temp1 = __PARAM1
  SERIN SIN, Baud, temp2
  __RAM(temp1) = temp2
  RETURN temp1
```

As you can see, the subroutine is expecting an address to be passed as a parameter (we can tell because the \_\_RAM array expects an address). If we forgot to put the "@" symbol in front of the destination variable name, the value received by the serial port would not go where it was intended, and this could be frustrating to track down.

Let's see the same subroutine that returns a value:

```
RX_BYTE:
  SERIN SIN, Baud, temp1
  RETURN temp1
```

I think you'll agree that the second version is easier — and it even uses one less variable.

The other neat feature recently introduced in SX/B is string (address) handling. It's a little more involved, so let's save that for our project.

## Cheap PC Control

There's no denying that PCs are cheap — so much so that it's no longer out of the question to dedicate a PC to a control task. As I mentioned earlier, I got a lot of mail regarding the MIDI project. While many were interested in it, not everybody wanted to invest in MIDI control software, especially when the control might be localized.

At about the same time, my friend Rick showed me a new product he was developing for the gas industry. It's a



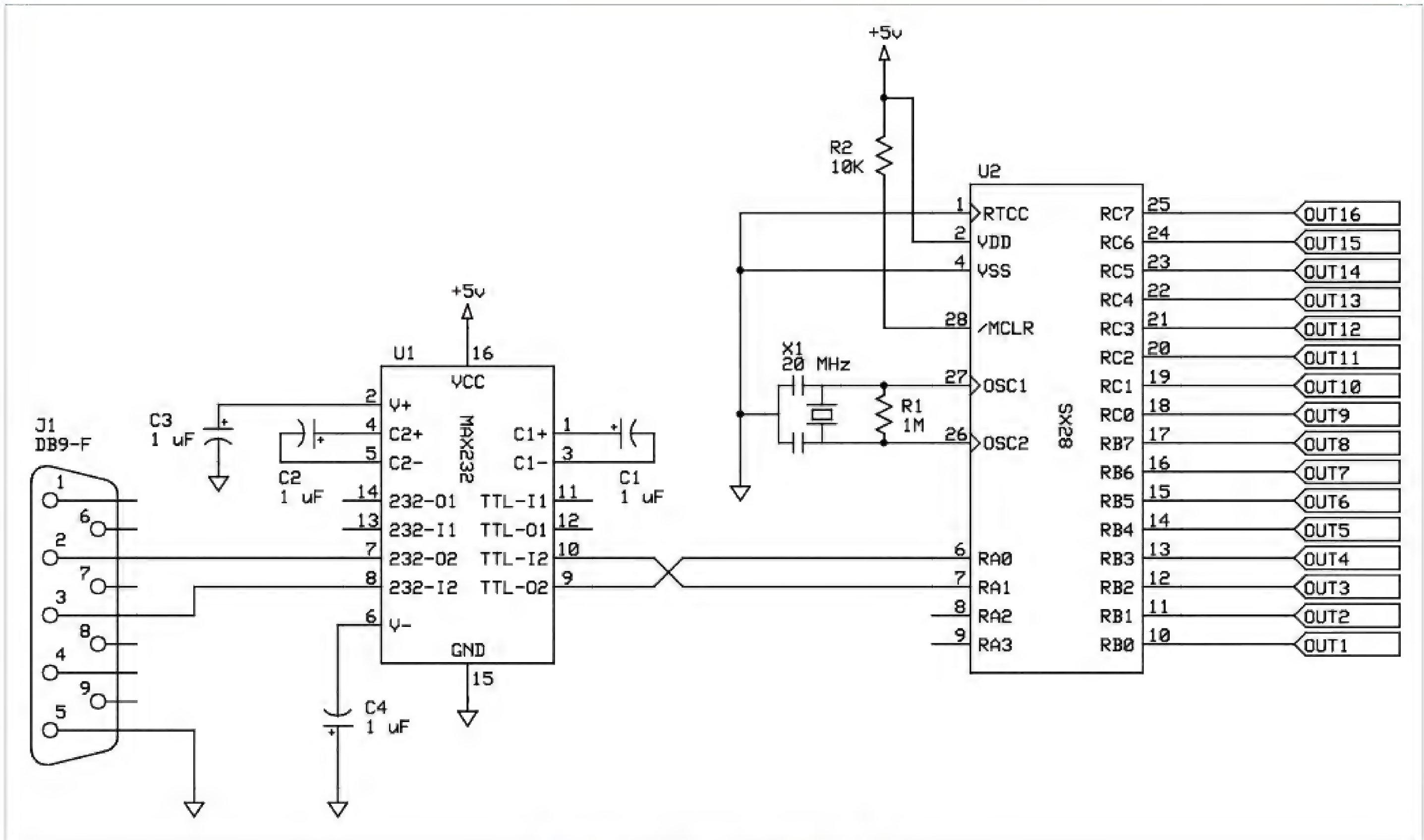


Figure 1. PC\_PORT16 Schematic.

very modular system with components that are connected through a multi-drop RS-485 link. What was particularly interesting is that Rick chose to use a text interface between the devices. By using text to move data, Rick is able to monitor and control the system through a standard terminal program. Since the data moving back and forth is relatively sparse, the downside of having to convert to and from text is greatly outweighed by the simplicity of using a terminal program as a monitor and debugging tool.

Figure 1 shows the schematic for this month's project, which really doesn't get much simpler: a SX28 and a MAX232 level converter so we can connect to the PC. I haven't done anything with the outputs (RB and RC), as you'd have to decide what you're actually going to control before you connect to them. Start with LEDs to get the program working, and then connect whatever happens to be appropriate. It might be a ULN2803 for driving relays or solenoids, or a solid-state relay (SSR) like the Crydom D2W203F-11 for controlling AC circuits.

Our goal this month is to create an interface between a generic terminal program and the SX. Figure 2 shows an example session using HyperTerminal. Once the [derivative]

project is working through a terminal, it's a very simple matter to control the device from our favorite PC development tool: VB, C, Java, Python, Perl — you name it; the interface is just text.

As I mentioned, SX/B 1.4 makes string handling easier for the programmer. We still have to write a subroutine to transmit the string to an external device, but the setup

Figure 2. Terminal Session.



for sending a string is now a single-step process. At the top of our control program, we'll define a bunch of zero terminated strings (z-strings) in **DATA** statements, much in the way we do it in the BASIC Stamp:

```
Prompt:
  DATA CR, LF, ">> ", 0

Version:
  DATA CR, LF, " PC_PORT16 Version 1.0", CR, LF, 0

Pad:
  DATA CR, LF, " ", 0

CRLF:
  DATA CR, LF, 0

PortStatus:
  DATA CR, LF, " Ports = ", 0
```

Note that the strings also contain constant values for carriage return (CR) and line feed (LF) that are also defined in the program (i.e., they are not built into SX/B).

It is our responsibility to write the subroutine that handles the string because SX/B has no idea where it's going to go. In this program, we'll send it to the PC using **SEROUT**. First, of course, we need to define the subroutine for the compiler:

```
TX_STR          SUB      2
```

As you can see, a subroutine that handles a string requires two bytes: the base address and character offset (these will be handled by the compiler when we make the call to TX\_STR). The reason for this is that the SX's [native] IREAD instruction will be used to pull a character and it requires a 12-bit address. Here's the code for TX\_STR:

```
TX_STR:
  temp3 = __PARAM1
  temp4 = __PARAM2
  DO
    READ temp3 + temp4, temp5
    IF temp5 = 0 THEN EXIT
    TX_BYTE temp5
    INC temp4
    temp3 = temp3 + Z
  LOOP
  RETURN
```

We start by saving the base address and character offset in variables *temp1* and *temp2*. Then we enter a loop that uses **READ** to pull a character and, if the character value is not zero, we send it to the PC with TX\_BYTE. By using variables for the base and offset, both can be updated, allowing the string to cross SX page boundaries. This makes our life simple, and the 1.4 compiler even lets us do this:

```
TX_STR "Hello, World!"
```

Yes, we can embed a string right into the program code. A note of caution, however: the string will be embedded in place (the terminating zero is added by the compiler); if we're going to use the same string more than once, then using this style is not the best choice. Just to clarify, when a string is going to be used in more than one place in the program, then the best thing to do is put that string into a **DATA** statement.

As we just saw, TX\_STR calls TX\_BYTE to send the character to the PC at the specified baud rate (115.2 kBaud in this program). Let's have a look at that code:

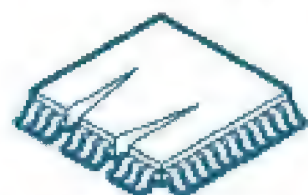
```
TX_BYTE:
  temp1 = __PARAM1
  IF __PARAMCNT = 1 THEN
    temp2 = 1
  ELSE
    temp2 = __PARAM2
    IF temp2 = 0 THEN
      temp2 = 1
    ENDIF
  ENDIF
  DO WHILE temp2 > 0
    SEROUT SOut, Baud, temp1
    DEC temp2
  LOOP
  RETURN
```



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This routine requires at least one parameter, and can take two. The second parameter (if provided) will be the number of times to transmit the character. So, if we want to send a string of 20 asterisks, we can do this:

```
TX_BYTE "*", 20
```

Working our way through TX\_BYTE, we start by saving the character to transmit in *temp1*. Then we check the number of parameters sent by looking at \_\_PARAMCNT. This is an internal variable and set by the compiler based on the syntax we use (one parameter or two). If only one parameter was sent, then *temp2* will be set to one; otherwise we set it to the second parameter. Since I don't think it makes sense to send a zero in the count parameter, the subroutine traps this condition and changes it to one.

The actual transmission of the character is done in a **DO-LOOP** construct that uses the count (*temp2*) parameter for control. Each time through the loop, the character is sent and the count variable is decremented. When the count reaches zero, the loop terminates and the subroutine is finished.

Okay, then, let's get into the program. After initialization, the program sends a prompt to the terminal (or control application) and then waits for input. In this case, the input will be a command character followed by a carriage return.

```
Main:
TX_STR Prompt
cmd = RX_BYTE
IF cmd = CR THEN
TX_STR CRLF
GOTO Main
ENDIF
char = RX_BYTE
IF char <> CR THEN
TX_STR CRLF
GOTO Main
ENDIF
```

The reason I decided to follow the command character with a forced CR is that it allows me an "Oops!" condition in the event I press the wrong command key (some keys are expecting data that will change the SX outputs). If I press the wrong key, then all I have to do is hit Esc or any other key (except CR) to get back to the prompt without consequence.

The program uses RX\_BYTE to get a byte from the terminal. One of the things that this program does is convert letters to uppercase — this simplifies our command letter processing.

```
RX_BYTE:
SERIN SIn, Baud, temp1
IF temp1 >= "a" THEN
IF temp1 <= "z" THEN
temp1 = temp1 - $20
ENDIF
ENDIF
RETURN temp1
```

As you can see, this subroutine is quite simple; we wait for a character, then examine it to see if it falls between "a" and "z" (inclusive). If it does, then we subtract \$20 from the character (ASCII code) to convert it to uppercase before returning it to the caller.

With a command character in hand, we can compare it against a known list of commands and jump to the code that handles that. In the BASIC Stamp, we frequently use **LOOKDOWN** and **BRANCH** to handle this sort of processing, but in the SX, I prefer to use straightforward **IF-THEN** statements; in SX/B — because of the way code is compiled — it seems to result in more efficient assembly output. (Have a look at the compiled source using Ctrl-L to see what I mean.)

```
IF cmd = "V" THEN Show_Version
IF cmd = "G" THEN Get_Ports
IF cmd = "S" THEN Set_Ports
IF cmd = "H" THEN Set_HiPort
IF cmd = "L" THEN Set_LoPort
IF cmd = "P" THEN Set_OnePort
IF cmd = "R" THEN Reset_Ports
```

As you can see, it would be quite easy for us to add new commands to the list. Let's have a look at how each command is handled.

Insert creativity here

...and here

...and here

...and here

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The first command is “V” for Version. This feature may be important if we develop a piece of control software that can work with multiple control devices; getting the version (hence, available features) from the connected device will prevent possible incompatibility issues.

```
Show_Version:
  TX_STR Version
  GOTO Main
```

Boy, that was tough, wasn't it? Since we've already covered sending strings, there's really nothing else to cover.

Next is “G” for Get Ports Status. This command will return the status of the 16 output ports in this form:

```
Status = 00000000 00000000
```

Note that what follows “Status =” are the actual states of the pins, where “1” is on and “0” is off, and the display is MSB to LSB. What we need to do here is create a subroutine that will transmit a value as a binary string, much the way the PBASIC BIN8 modifier does.

First, the Get\_Ports code:

```
Get_Ports:
  TX_STR PortStatus
  TX_BIN8 PortHi
  TX_BYTE " "
  TX_BIN8 PortLo
  TX_STR CRLF
  GOTO Main
```

And now the TX\_BIN8 subroutine that is used by Get\_Ports:

```
TX_BIN8:
  temp3 = __PARAM1
  FOR temp4 = 1 TO 8
    IF temp3.7 = 1 THEN
      TX_BYTE "1"
    ELSE
      TX_BYTE "0"
    ENDIF
    temp3 = temp3 << 1
  NEXT
  RETURN
```

The TX\_BIN8 subroutine, of course, expects a value to be sent; this will be saved in *temp3*. Using a **FOR-NEXT** loop, the bits are examined from MSB to LSB. If the bit is set, then we use TX\_BYTE to send “1” — otherwise we send “0.” Since *temp3* is a work variable and doesn't need to be preserved, the code is simplified by looking only at the MSB. In order to examine all of the bits, *temp3* is shifted left each time through the loop. This moves the next bit into the MSB.

Okay, now that we can see the outputs, how do we change them? The program supports three different methods of updating the outputs: all 16 at once, the high

and low groups, or individual port bits. Let's start with all ports using the “S” (Set All Ports) command:

```
Set_Ports:
  TX_STR Pad
  PortHi = RX_BIN8
  TX_BYTE " "
  PortLo = RX_BIN8
  TX_STR CRLF
  GOTO Main
```

For the Set\_Ports code, we need a routine that is the complement of TX\_BIN8 — in this case, it's RX\_BIN8. This will allow use to receive a value expressed in binary form, and is used to accept values for the high port (RC) and low port (RB) separately. A space is transmitted after the receipt of the *PortHi* value to indicate a new input (for *PortLo*).

```
RX_BIN8:
  temp3 = 0
  FOR temp4 = 1 TO 8
    temp5 = RX_BYTE
    IF temp5 >= "0" THEN
      IF temp5 <= "1" THEN
        temp3 = temp3 << 1
        IF temp5 = "1" THEN
          INC temp3
        ENDIF
      ELSE
        EXIT
      ENDIF
    ELSE
      EXIT
    ENDIF
  NEXT
  RETURN temp3
```

We start by clearing *temp3*, which will ultimately hold the return value. Then we set up a **FOR-NEXT** loop to get eight bits. A character is retrieved from the serial port and checked to see if it's a valid binary digit: “0” or “1.” If it is, then the return value is shifted left and the new bit value is added to the return variable. Shifting left means that the routine is expecting the value to be transmitted MSB first.

The **FOR-NEXT** loop takes advantage of **EXIT** to terminate early if a non-binary character is sent before the end of the loop. This allows us to enter the minimum number of bits required to express the value. If, for example, we enter “1111” and then press space, the value 15 will be returned to the caller.

There are two additional commands, “H” and “L,” that allow the user to set the high and low ports independently. Those routines are simply subsets of the Get\_Ports code.

I think the trickiest aspect of this program is the code for “P” (Set Individual Port), that allows the user to specify a port number (1 to 16) and its condition (0 for off, 1 for on). For this code, we'll need a routine that will accept a decimal value: RX\_DEC2.



```

RX_DEC2:
temp3 = 0
FOR temp4 = 1 TO 2
temp5 = RX_BYTE
IF temp5 >= "0" THEN
IF temp5 <= "9" THEN
temp3 = temp3 * 10
temp5 = temp5 - "0"
temp3 = temp3 + temp5
ELSE
EXIT
ENDIF
ELSE
EXIT
ENDIF
NEXT
RETURN temp3

```

While it may not seem so at first, this code is identical to the RX\_BIN8 subroutine. The difference, of course, is in the decimal base. To "shift" digits in this code, we need to multiply by 10, and then add the new value (after it's converted from its ASCII code) to the result. Since we're dealing in decimal and don't want to overrun the limitations of a byte, the subroutine allows a maximum of two digits.

And now it gets a little hairy — but just a little.

```

Set_OnePort:
TX_STR Pad
idx = RX_DEC2
TX_BYTE " "
cmd = RX_BYTE
IF idx >= 1 THEN
IF idx <= 8 THEN
DEC idx
temp1 = 1 << idx
IF cmd = "1" THEN
PortLo = PortLo | temp1
ENDIF
IF cmd = "0" THEN
temp1 = ~temp1
PortLo = PortLo & temp1
ENDIF
ENDIF
IF idx >= 9 THEN
IF idx <= 16 THEN
idx = idx - 9
temp1 = 1 << idx
IF cmd = "1" THEN
PortHi = PortHi | temp1
ENDIF
IF cmd = "0" THEN
temp1 = ~temp1
PortHi = PortHi & temp1
ENDIF
ENDIF
ENDIF
TX_STR CRLF
GOTO Main

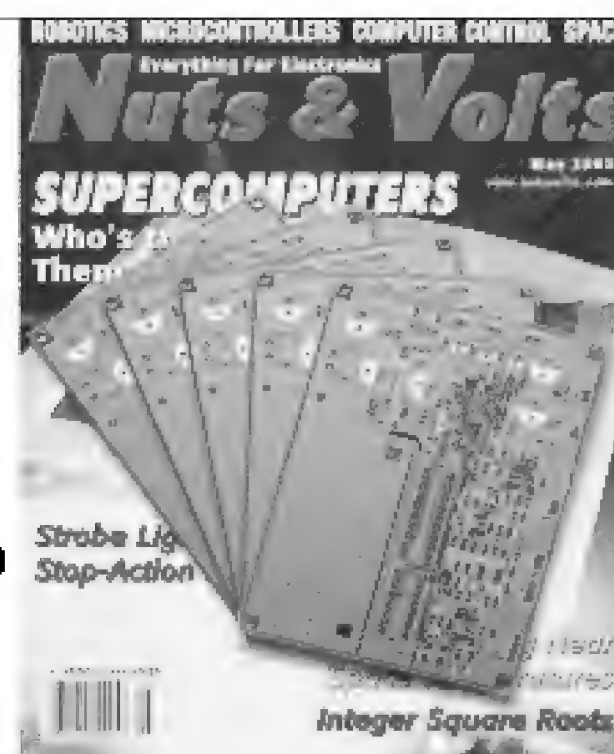
```

This code is not as bad as it looks at first blush. What we have to remember is that SX/B is very close to assembly language (many instructions are 1-for-1), so it gets a bit verbose — certainly more than PBASIC.

The code waits for the port number, prints a space pad,

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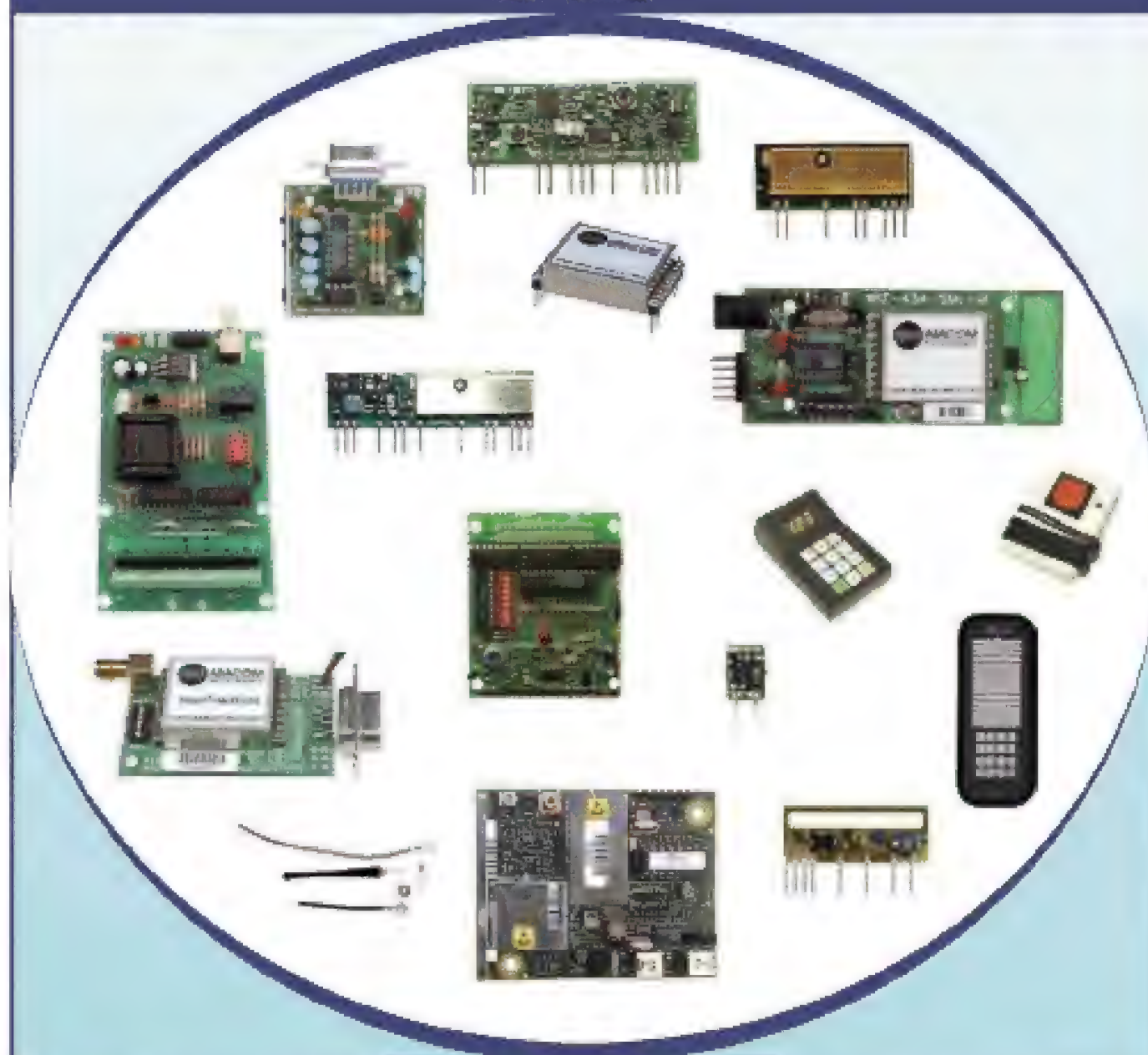
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and then waits for a state value. The port value passed is compared against valid ranges: 1-to-8 for the low port, and 9-to-16 for the high port. If the value sent to the program falls outside of either range, this section terminates and goes back to Main.

For analysis, let's assume that the user entered a port value of "4" and a state value of "1"; the user wants to turn output 4 on. First we zero-align the port value based on the group that will be updated, and then a mask is created from this value. In this case, the port 4 value gets converted to a pin-mask of %00001000. If the state is "1" then the mask is ORed with the appropriate SX port to enable the specified bit. If the state is "0" then the mask is inverted and ANDed with the SX port to clear the selected port bit. Finally, we have the "R" command to reset (clear) the outputs.

```
Reset_Ports:
PortHi = %00000000
PortLo = %00000000
TX_STR CRLF
GOTO Main
```

Nothing magic here — simply clear the ports and go back to the top.

That about does it. I hope that you learned something from this project and that you can use it as the starting point for some neat PC-based control projects. And, by the way, if

you need more ports, remember that the SX48 and SX52 are available — and Parallax is selling fully-populated SX48 and SX52 proto boards for 10 bucks! With this framework code and all those I/O pins, there's no limit to what you can do.

Before I close, let me explain something. You may have noticed that I always use the variables *temp1* through *temp5* in my SX/B subroutines. There is a method to this apparent madness. What we haven't really discussed yet is that SX/B allows external files to be included in a listing, so by being consistent with subroutine variable names, it's easier to bundle common routines like RX\_BYTE and TX\_BYTE in a separate file. Then we can do this:

```
LOAD RXTX.SXB
```

Cool, huh? Yeah, I think so too.

Have fun with the SX and until next time, Happy Stamping! **NV**

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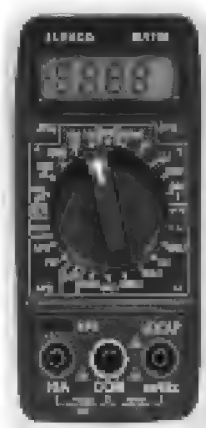
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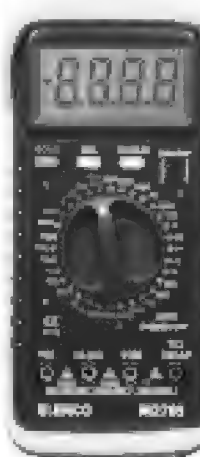
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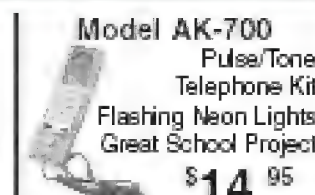
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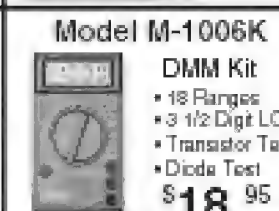
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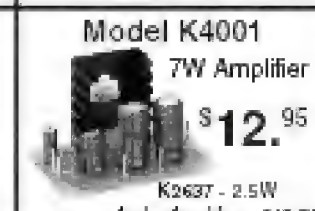
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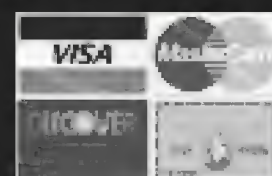
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# In The Trenches

## Software Development

**F**rom time to time, most engineers are required to develop software. Some have training for this and others don't. Sometimes the training is inappropriate for the task at hand. This month, we'll look at approaches and considerations that are important in developing good software.

### Top Down, Bottom Up, or Gestalt

There are three general approaches for writing a computer program. The most general is the gestalt or all-in-one approach. This is typically used for very short programs or by inexperienced programmers. With this technique, the program is written as a block. It is then compiled and debugged as a whole. The Holy Grail for this approach is to have a perfect program the very first time. (It's never happened to me.)

The big problem with this approach is that there are many ways that a program can fail. Worse, the same failure can have several different causes. If there is a problem with an output value, for example, it could be that the calculations are incorrect, the wrong table data is being read, or the output columns are reversed.

Trying to figure out the source of the error can be extremely difficult, frustrating, and time-consuming, which is why this approach is rarely used for serious software. (Of course, when you were graded on how many times you submitted the program for compilation, this approach had its merits. But that was way, way back then. This is now.) The top-down approach is often used for large software projects where there are a number of members working on it simultaneously. In this case, the logic core of the program is created and test-

ed first. Then the individual sub-programs, often written by different people, are plugged into the core and tested.

Clearly, this approach is better than the gestalt method. The software is developed piece-wise, with each piece developed and debugged in isolation. The result is a series of modules that are moderately independent of one another, which allows individual modules to be modified fairly easily when needed. This approach is usually applied with "real" computers (desktops, networks, and mainframes) that provide ample tools for examining how the code operates internally. High-level languages are typically utilized.

The bottom-up method is usually employed for embedded computer and microcomputer (uC) applications. In this approach, the subroutines are written and tested first. After these modules are completed, they are then assembled into a program with the appropriate logic.

Again, this approach is clearly superior to the gestalt approach. It is similar to the top-down method, in that separate modules are created. This simplifies debugging and changing the code. Typically, a single person writes the software. The tools for examining the code internally are usually more limited, and low-level languages are employed more often. The choice between top-down and bottom-up development can be somewhat arbitrary. If there are several people working on a software project, then top-down is probably a better approach. But if it's just you, choose whichever method you feel most comfortable with.

### Language Choice

The choice of a programming lan-

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guage will have a significant impact on the development of the software. You certainly don't want to design web pages with COBOL or a database manager in Postscript. Generally, the language choice will be fairly obvious. There are a number of specialized languages for specialized applications. For generic software, a general-purpose language is appropriate.

To limit the scope of discussion, let's look at one-person software development that supports a hardware product. For example, this could be a uC that controls a microwave oven or a PC-based data-acquisition system.

For PC-based software, you will clearly want to use a high-level language. There are several specialized languages available, and you should learn which of those are appropriate for your application. Most general programming is done with a variation of the C language; C+ and C++ are the most common. These are good general-purpose languages that are suitable for many applications.

For uC applications, assembly language and C+ are typical. However, an important stipulation is that you should always be proficient in the assembly language for that uC because there are times when a high-level language creates too much overhead for efficient code. For real-time applications, it is not unusual to require the maximum speed of the uC. This can only be accomplished in assembly. Additionally, if you don't know assembly, you are at the mercy of limitations of the high-level language.

## Basic as a Language Choice

Basic (Beginners All-purpose Symbolic Instruction Code) is easy to learn and has lots of useful instructions. However, it is not a good choice for commercial software development. Before I get a lot of angry letters, let's examine why this is the case.

First, Basic is an "interpreter," while most other languages are compiled. This difference is very important. A program that is compiled

(sometimes called "assembled") is converted into machine language by an external program called a compiler (or assembler). This machine language translation is then loaded into the computer and executed. The compiler is only used during translation, not during execution.

An interpreter permanently resides in the computer and converts one line

of code into machine language and executes that code immediately. Then it takes the next line of code and converts that, and so forth. This line-by-line conversion/execution method is slow, but it has the advantage of being easy. You don't have to load a compiler, link various files, set compilation attributes, and so on. You just hit "RUN." For beginners, this powerful simplicity is

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important. It allows the student to concentrate on the program logic instead of the technical details of converting the Basic code into machine language. That's a major reason why Basic is easy and fast to learn.

You can also see that Basic is a program that must always be present in the computer. This means that some fraction of the computer's memory must be allocated for it. Obviously, this reduces the available resources for your program. This may not be an important consideration for a large computer, but for uCs, the Basic Interpreter can take up most of the available memory.

Note that there are Basic "compilers" available that take a Basic program and convert the whole thing into machine language, which is then loaded and run alone. This speeds up the execution and eliminates the need to allocate memory space for the interpreter. However, it doesn't fix one last problem. This last problem is that Basic has no real structure. This is very useful for the student because there is no need to understand or specify (initially at least) data types, word sizes, memory allocation, and so on. Again, all the student has to focus on is the logic of the program. But complex software needs structure.

I view Basic as the equivalent to white "proto-boards." It's very easy to get a simple circuit up and running. It's easy to change. But no one would consider mass-producing a product with a proto-board inside. Note that I do use Basic and think it's great for the purpose for which it was designed. But it's important to remember that it was designed as a learning tool — not for creating commercial software.

## My Approach

Since I've been programming all sorts of computers since the IBM 1130, my experience may be helpful. I generally use the bottom-up approach because I'm usually the only one working it. I always do the output routines first so that I can later use them to display whatever I want to look at. Often, this is faster than invoking a simulator and creating input files for testing. This is especially true with analog inputs.

If I am using analog inputs, I write those input routines next. I use the output routine to verify that the analog code is operating properly. I always keep this output routine in the program for possible future use. It comes in handy if a change causes problems. Often, I include it in the self-

test routines. If not, I convert the code to comments so it doesn't use any resources but is there when I need it.

I then proceed to work through the program, routine by routine. Generally, I'll develop related routines in sequence. For example, if I have to manipulate an analog input, I'll do that right after I've done the input routine. It's convenient. One thing I do that bothers some people is to add the comment "TESTED AND WORKING" to every module that has been verified. This way I never have to wonder, several weeks later, if I really tested it. Additionally, it's nice to see those milestones achieved. It's a good idea to keep a library of routines you develop. It obviously saves a lot of time and effort to re-use code rather than re-invent it. For example, there will always be applications where you drive seven-segment LEDs for uCs. Therefore, you will need a binary-to-seven-segment LED conversion routine. If you make it fairly general to begin with, you'll be able to easily use it repeatedly.

## Creeping Mediocrity

I rarely use routines written by someone else, even those supplied by the manufacturer. The reason I write my own routines is because I hate being dependent upon someone else's expertise, or lack thereof. Most likely, the subroutines provided by the manufacturer work properly. But what if they don't? You will find a disclaimer in every applications note saying that the code is not guaranteed to work. Additionally, there are often many ways to approach a given problem. How can you be sure that the approach someone else used is the best approach for you?

I call this creeping mediocrity because there seems to be a growing tendency to depend upon someone else's expertise, rather than on your own. This is partly because systems are becoming increasingly complicated and partly because there is greater pressure to get to market in the shortest possible time. There is also the mistaken notion that whoever wrote the

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subroutines must be smarter than you.

Let's look at two concrete examples. The first concerns a major ASIC (Application Specific Integrated Circuit) manufacturer. A number of years ago, I used ASICs, which can be thought of as consisting of a large number of small programmable logic devices with a fixed number of programmable interconnections. I had been developing these "by hand." That is, I would define the logic and figure out the best way to interconnect them by myself. But, as the ASICs got more and more dense, developing them by hand became unworkable.

I bought very expensive development software that would design an ASIC from a schematic diagram. At the training class, I noticed that if a flip-flop wasn't using the "Reset" function, it was shown as grounded in the schematic. This was odd because the flip-flop logic could be configured without a reset at all. Grounding it wasted an input to the logic device, as well as wasting interconnect resources to wire it to ground. Overall, this resulted in wasting about 10% to 20% of the ASIC. Therefore, anyone who employed this tool without understanding its implications could never fully use the power of the ASIC.

A potentially more serious example is with Anti-lock Braking Systems (ABS) on cars and trucks. Here, a computer detects when the wheels stop turning and briefly releases the brakes in order to prevent a skid. It sounds great and works pretty well most of the time.

With ABS, a good driver can generally come to a stop in about 10% less distance on dry pavement. However, on newly fallen snow, dirt roads, and some gravel roads ABS works very poorly. The stopping distance is increased by 100% to 200% over that of a good driver, because on these roads, you want the wheels to lock up. In lock-up, the snow, dirt, or gravel builds up in front of the tire and acts like a wedge or wheel chock. With ABS, the vehicle just rolls and rolls and rolls. You don't skid, but you don't stop, either.

There are software products to

automatically create websites. There are products that write interface code for you. There are products that claim to make everyone in the department an expert. Some are good, and some aren't. All of them make every user equal. Unfortunately, this equality — whether it's ASIC design or web-page layout or something else — is rarely better than average. And if everyone is an "expert," then no one is. Besides, do you really want to rely on someone else to do your work for you?

Note that I am not against progress or new approaches. I appreciate novel ideas and products that save me time. It's critical, however, to maintain control of every aspect of a project. It's hard to believe that some stranger thousands of miles away knows my project better than I do. I also enjoy thinking for myself.

Lastly, by using pre-developed software products, you are helpless if anything goes wrong with that part of the project. If you didn't know how to design it to begin with, how can you fix it? Control, experience, and training are elements of a project for which the designer is responsible. You can't get these out of a box, any more than you can take a pill as a substitute for exercise.

## Self-test

The need for self-test routines for any hardware interface can't be overstated. If there is a bad component, it is critical to know this before trying to execute any instructions. With a jammed motor or a faulty sensor, the program can be a menace to lives and property.

Developing self-test code doesn't have to be difficult. If you've been writing test code as you developed the software, most of the work is already done. All you have to do is assemble the modules into a logical framework. (Can anyone say bottom-up programming?) Of course, if you plan to use these test routines from the start, you can make the assembly effort easier still.

One important point often ignored is to make your error messages clear, and simple enough to be understood by anyone. There is nothing more frustrating than getting a cryptic error message that makes no sense. Tracking down the documentation isn't always easy. For clarity, use the best available means that your hardware provides.

Another use for self-test routines is in production. Most self-test code measures some aspect of the hardware. Often this is useful to know during the fabrication of the product, as it

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can eliminate the need for additional test equipment and test procedures.

For example, I had a project that required optically sensing the teeth on a wheel. It was an easy matter to display how good the sensor signal was so that the assemblers could align it properly. It was very simple to incorporate it into the self-test, but it saved lots of time and effort. It also improved the quality of the product. When writing self-test procedures, try to put yourself in the position of the user. Provide the information that you would find important or useful, so that the user has the tools needed to conduct the tests.

## Documentation

Any discussion of software wouldn't be complete without including the topic of documentation. I devoted a column to this in May 2003, so I don't want to repeat myself here. I'll just touch on the important points.

Documentation, like the self-test routines, should be created while the software is being developed. It's not something to add on at the end. By then, the reasons why a particular procedure was implemented may be forgotten, and the time crunch to finish the product may supersede the need for documentation. Take notes during the development and testing of the code. Put lots of comments in the program itself, making them clear and accurate. In addition to assisting in writing documentation, these elements will help you during development.

I much prefer a state diagram to a flowchart. A state diagram shows a module's inputs and outputs and the conditions required for choosing them. Modules can be as small as a paragraph in a program or as large as a whole sub-program. If it's a sub-program, then it can have a lower-level state diagram, as well. State diagrams are useful because it's easy to see the

flow of the software. They're simple to create and maintain, which means that there's a real chance that it will be accurate.

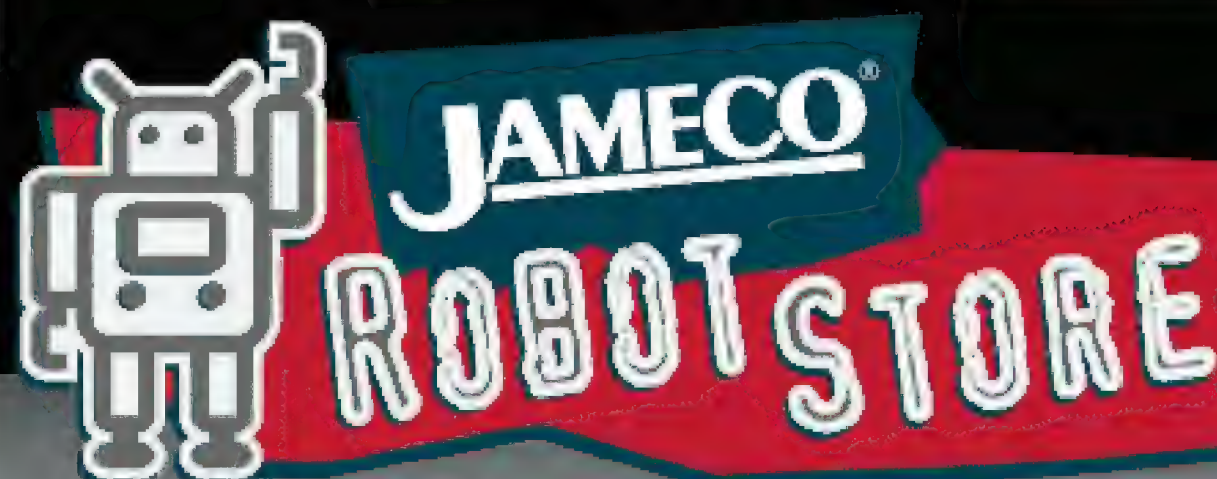
All documentation should be clear, accurate, and complete. Of these three, clarity is the most important. If the documentation is clear, inaccuracies will stand out and missing sections will be apparent. Again, provide what you think you would find useful and important.

## Conclusion

Not only is it important to understand the fundamental aspects of software development, but also understand that creating good software requires effort. If you plan your approach from the beginning, using the proper tools and techniques, this effort will be leveraged. The quality of the product is determined by the experience, training, and control of the designer. **NV**

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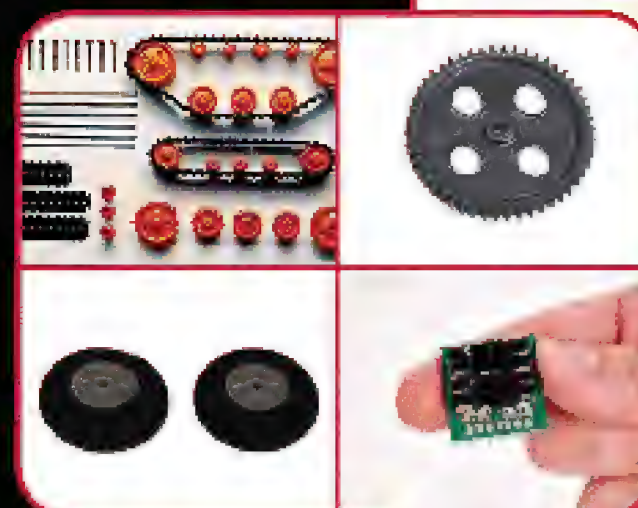
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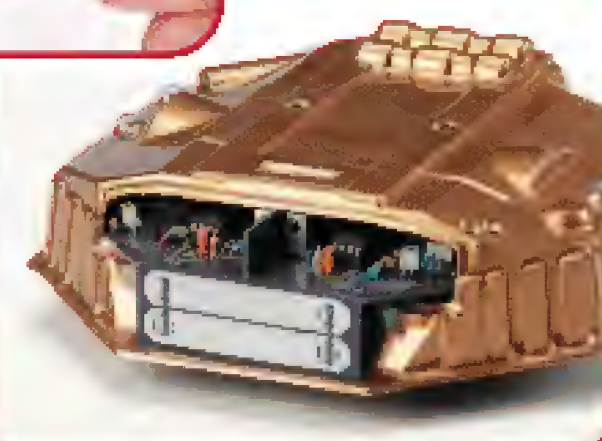
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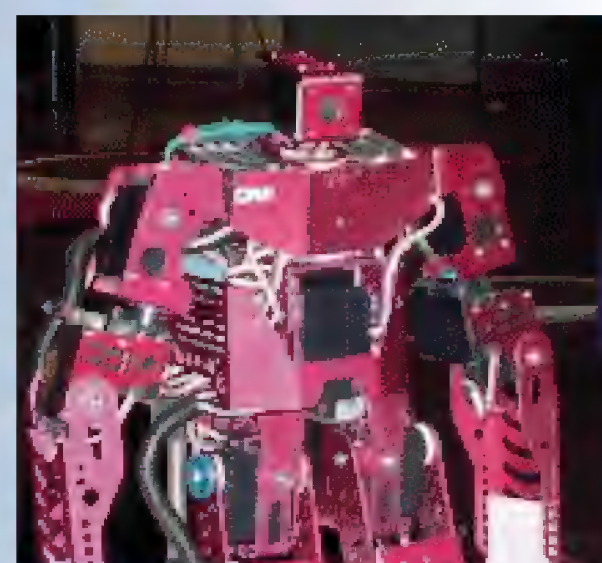
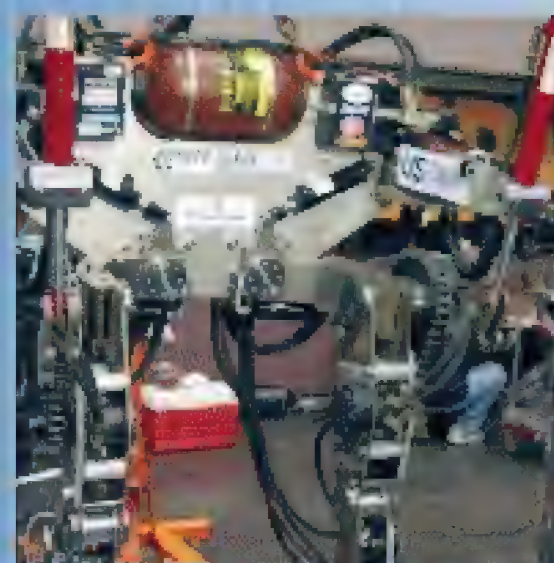
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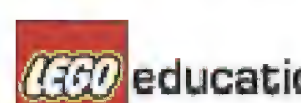
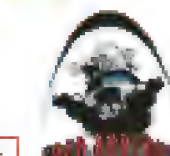
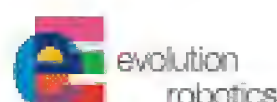
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# Near Space

## The Space Elevator

**T**oday, payloads are hurled into space on (still) expensive rockets. To get the best performance, these rockets push their design to the limit. And, as a result, considerable time and many people are required to build and prepare a rocket for launch. It's the cost of paying salaries that makes rocket launches so expensive; rocket fuel is actually cheap.

While an airplane is reusable — a feature which offsets the plane's high initial cost — so far, no rocket is totally reusable. Imagine how long an airline carrier would stay in business if it took a thousand people six months to get one of their airplanes ready for flight, and then they threw away a major chunk of the airplane in the process of getting it across the country.

Is there a better alternative to sending cargo into space on rockets? Many people think so. This article discusses one possible solution: the Space Elevator (SE).

### Introduction

*"Reach low Earth orbit and*

*you're half way to anywhere in the Solar System."*

— Robert Heinlein

The concept of the Space Elevator has been around a very long time. Stories like Jack and the Beanstalk reflect the popularity of reaching extreme altitudes by climbing tall towers. Today's version of this dream is the SE. The SE is a device for sending a payload into space without the fuss or muss of a rocket launch. The SE, as envisioned by its supporters, would create airline-like service to Earth orbit. But, before describing the SE in detail, let's briefly look at its history.

### History

The oldest mention of the SE that I have come across is by Konstantin Tsiolkovsky. A high school teacher before the Russian Revolution, Tsiolkovsky single-handedly developed most of the space travel concepts we take for granted. His book, *Day-Dreams of Heaven and Earth* (1895), explains what happens as you climb an extraordinarily tall tower. His reasoning and results went like this:

There are two forces acting on a body standing on a rotating body: gravity and centrifugal force. Earth's gravity pulls you towards the center of the planet. The reach of gravity is

infinite, although weaker as you move farther away. The only reason astronauts float inside the Space Shuttle is that both they and the spacecraft are in free fall around Earth. Stop the Shuttle's motion, and gravity will reappear for the astronauts — although weaker because of the Shuttle's 300-mile altitude.

Your momentum, generated by the rotation of Earth, will fling you eastward if Earth's rotation is halted. Your motion, when it's viewed from a rotating frame of reference (like the rotating Earth), has the appearance of a force directed away from the center of Earth. This pseudo-force is called centrifugal force. However, to an inertial frame of reference, one that is moving at a constant speed and direction, there is no centrifugal force — there's only gravity and your momentum. Unlike gravity, centrifugal force is not a true force. It's only used to simplify kinematic problems on a non-inertial frame of reference, like a rotating planet.

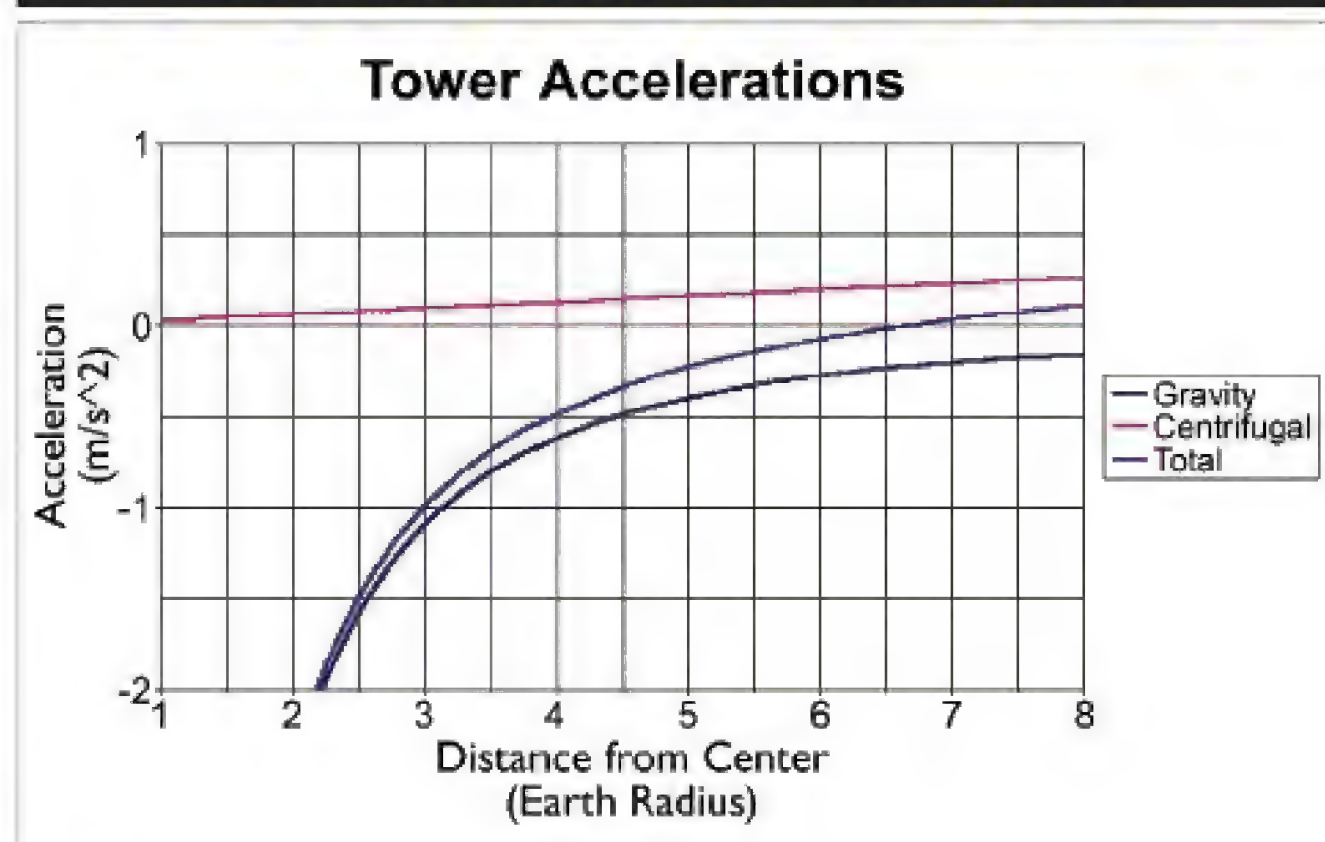
Forces, like gravity and centrifugal force, create acceleration. The acceleration due to gravity depends on the mass of Earth, the inverse of the square of the distance from its center, and a constant called the Gravitational Constant (G). The following equation calculates the acceleration due to gravity ( $A_g$ ) in meters per second squared ( $m/s^2$ ) when the radius from the center of Earth is given in meters.

$$A_g = G \times M_e / (R_e + h)^2$$

**Equation 1**

where the term,  $R_e + h$ , is the radius of Earth (6,380,000 meters) plus your height above sea level and,

**Figure 1.** As you can see, objects experience no net acceleration at a point 6.62 times Earth's radius away from the center, or 22,255 miles above the ground.





G is  $6.67 \times 10^{-11}$   
M is  $5.98 \times 10^{24}$

Doubling your distance from the center of Earth (not the altitude above sea level) decreases the force of gravity, the acceleration it creates, and your weight by a factor of four, that is,  $1/2^2 = 1/4$ . With Equation 1, I calculate that one of my near spacecraft at an altitude of 100,000 feet experiences a 1% reduction in Earth's gravity.

The acceleration due to centrifugal force depends on your velocity squared and the inverse of your distance from the center of rotation, or,

$$A_C = V^2 / (R_e + h)$$

**Equation 2**

When standing on a tower fixed to Earth's surface, your orbital period around Earth remains fixed at 23 hours and 56 seconds (rounded to 24 hours or 86,400 seconds). You can calculate your velocity by multiplying the height of the tower above the center of Earth ( $R_e + h$ ) by two times pi and dividing by the length of a day in seconds (86,400 seconds).

$$V = (2 \times \pi \times (R_e + h)) / 86,400$$

**Equation 3**

Substituting the equation for velocity (Equation 3) into the equation for acceleration (Equation 2) creates a single equation for calculating the centripetal acceleration,

$$A_C = (4 \times \pi^2 \times (R_e + h)) / 86,400^2$$

**Equation 4**

To determine the effect of climbing a tall tower, we combine the effects of gravity and centrifugal force. By combining the accelerations due to gravity (towards the center of Earth) and centrifugal force (away from the center of Earth), I was able to generate the following chart (shown in Figure 1) of total (or net) acceleration as a function of height above the center of Earth.

Tsiolkovsky's SE was a tower tall

enough to reach a stationary orbit for the planet it stood on. Cargo rode up the tower until it was in geostationary orbit and able to be released without crashing back to Earth.

Now, Tsiolkovsky didn't think it was possible to build a SE. For one reason, building a tower taller increases its weight. In order to remain standing, as the tower's weight increases, its strength must also increase. Without changing the nature of the tower, its strength is increased by widening it.

Since the weight of the tower increases as you approach the surface of Earth, the tower must get wider as you approach its base. However, widening a tower's base adds weight to the tower which, in turn, requires the tower's base to be even wider. At some point, we reach the maximum height permitted by the tower's construction and materials.

Yuri Artsutanov, a Leningrad engineer, performed the first serious engineering study of the SE in his paper, "Into Space with the Help of an Electric Locomotive." His study was published in 1960 in the pages of the Soviet newspaper *Pravda*. No one took notice of his results, perhaps as a result of publishing his study in a habitually dishonest newspaper.

Artsutanov's initial SE was one millimeter wide and capable of carrying 900 tons of cargo into geostationary orbit (I believe this is 900 tons per day). The beauty of Artsutanov's SE is that it can bootstrap itself. Only a thin ribbon needs to be flown into space. The tower's climbers then make trips up and down the SE, adding additional ribbons each trip. Once the SE was a thousand-fold stronger, it could lift 12,000 tons of goods per day to geostationary orbit, or the equivalent of one fully loaded Space Shuttle launch every four minutes.

A 1960s Convair feasibility study on the use of tall towers for astronomy, high altitude research, rocket launching, and communications determined that the tallest possible

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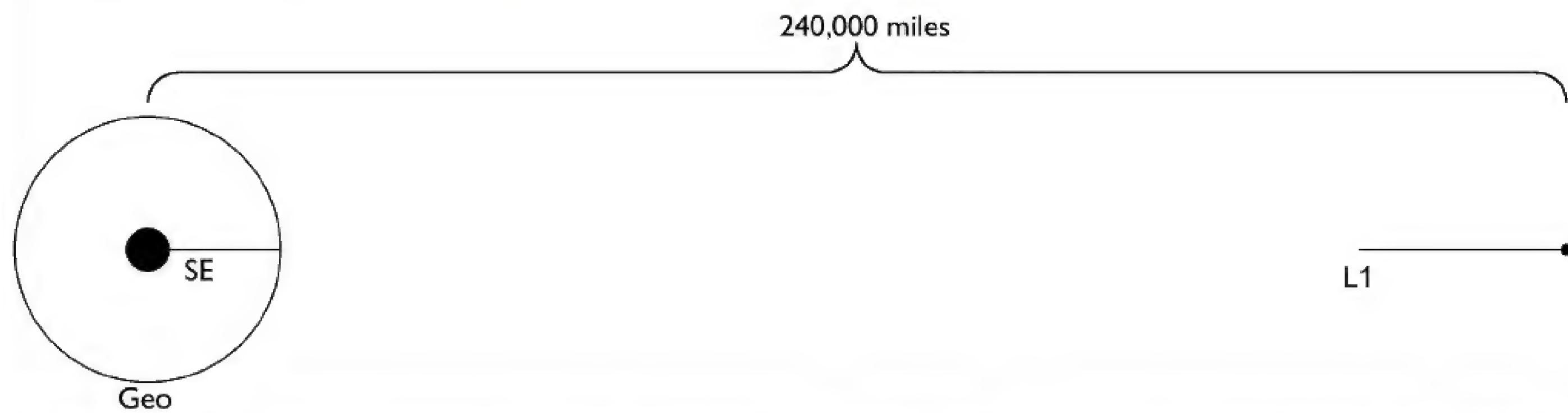
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**Figure 2.** A very close-to-scale drawing of the Earth and Moon. Depicted are a SE, geostationary orbit, and a lunar elevator. (Note: I did this diagram before I realized that the SE would extend above geostationary orbit in order to be put under tension. So in this diagram, the SE extends farther.)

steel tower is 3.7 miles and the tallest aluminum tower is 6.2 miles. Graphite composite is stronger than an equal weight of steel. As a result, the tallest a graphite composite tower can reach is an altitude of 24.8 miles. A graphite composite tower of this height requires a base 3.7 miles wide. Currently, the tallest artificial structure is the KTHI TV radio tower. Made of steel, it stands 2,063 feet tall. We only need to increase its height by a factor of 55,600 to turn it into a SE.

At a 1963 presentation at the Ames Research Center, Arthur C. Clarke told his audience to think of a satellite in geostationary orbit as standing on a tall tower. Jerome Peterson was listening that day and

thought, why not actually built a tower that tall?

Today, Pearson's company, Star Technology and Research, has developed an SE concept with the help of a \$75,000 award from NASA.

## Pearson's Lunar Space Elevator

Pearson proposes constructing the first SE on the Moon. With its lower gravity (1/6th of Earth's), the tower's weight is lower and this reduces its strength requirement.

As anyone who has observed the Moon knows, the Moon keeps its same face pointed towards Earth, though there's a slight wobbling

called libration. Since the Moon doesn't rotate, there's no such thing as a geostationary (lunastationary?) orbit around the Moon. However, there is a point where the gravity of Earth balances both the gravity of the Moon and the centrifugal force of the Moon being in orbit around Earth.

This balance point creates a location where a satellite remains stationary above the Moon and with respect to Earth. This point is called the First Lagrangian Point, or L-1, and is located on a line between the Earth and Moon 36,039 miles above the center of the Moon with respect to us on Earth (see Figure 2).

If you plot the direction of the forces surrounding the L-1 position,

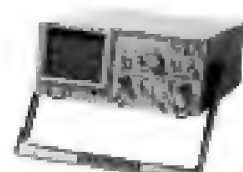
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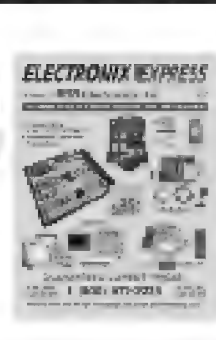


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you'll find that L-1 is more like a hill than a bowl. A marble remains stationary at the top of a hill, but give it a little shove and it becomes unstable and rolls away. The same is true of a satellite located at L-1. To remain at L-1, a satellite, or tower, requires active maintenance of its position.

There are four additional stationary points located within the Earth-Moon system and two of them, L-4 and L-5, are stable like a marble is at the bottom of a bowl. L-4 and L-5 will make great locations for space colonies and industry.

Materials strong enough to form a 36,000-mile-tall tower above the lunar surface exist today. Spectra (a kite string I use) and Kevlar are two of the suitable materials with which you're probably familiar. Pearson believes the best material is a fiber manufactured by Magellan Systems called M5. A 36,000-mile-long lunar SE made of M5, and with the strength to lift a climber and 400 pounds of payload, weighs only 15,000 pounds. That is small enough to be carried by a single Space Shuttle launch.

The climb up a lunar SE is slow, so it's not suitable for transporting people. However, the Moon contains resources useful for space colonies and exploration. A commodity like ice trapped at the lunar poles is useful as fuel and water. The Moon's raw dirt (regolith) is valuable as a shielding material for space colonies. To reduce the time required to haul lunar ice from the lunar poles to the lunar SE, a second lunar SE can be set up from a lunar pole to the L-1 position.

So engineering models show that the lunar SE is feasible today, but what about a SE on Earth?

## Back to the Earth-based SE

Otis, the elevator company, has developed the technology for five-mile high elevators. Within 10 years, they believe they can develop the technology for an elevator that can climb to geostationary orbit on an SE.

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Several SE papers were presented at the 55th Astronautical Congress in 2004. Several of the papers focused on an Earth SE constructed as described below.

The SE of the future begins as a 15-centimeter-wide ribbon launched into geostationary orbit. The ribbon bootstraps itself until it's a one-meter-wide ribbon. The base of the ribbon is tethered to a floating ocean platform, where it's protected from acts of terrorism and from the political upheavals possible in countries with unstable governments.

An additional benefit of tethering the SE to a floating platform is that there are equatorial regions where peaceful weather is the norm. For instance, hurricanes cannot form on the equator because the Coriolis Effect is nonexistent there. Orbital predictions are used to schedule movements of the floating platform in order to avoid orbital collisions between the ribbon and satellites.

Cargo is sent up the SE inside a climber — a climbing robot. SE climbers carry a photovoltaic array

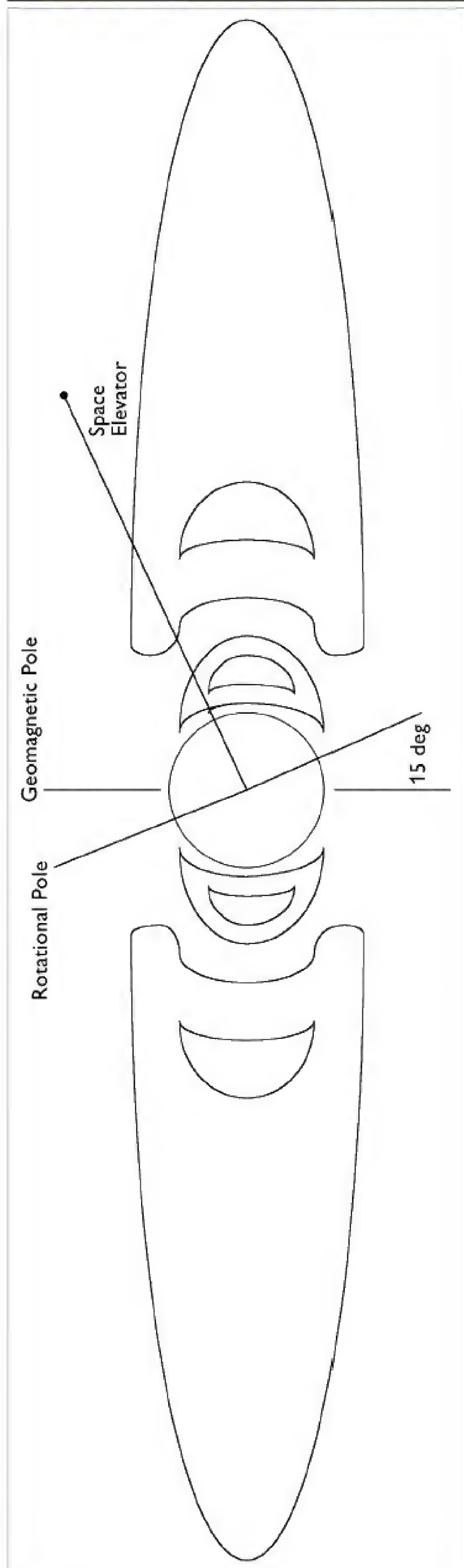
for power. Electrical power is beamed to climbers via lasers. Climbers use the electricity to scale the SE ribbon with a set of pinching rollers. Solid-state continuous lasers with 1 kW output currently exist and have efficiencies of 30%.

Combined laser modules form the SE power station. The ribbon is made from carbon nanotube (CNT) fibers embedded within a matrix. CNTs of the required strength exist today. To support the weight of the SE and its climbers, the SE ribbon must have a strength of 100 GPa. Current CNTs have a strength of 200 GPa, but only a length measured in millimeters.

The climbers are multi-functional robots. Not only do they climb the ribbon, but they also lay ribbon, identify ribbon damage, repair ribbon damage, and rescue stranded climbers. Transit time to geostationary orbit is 500 hours, so it's not a convenient system to carry people into orbit. Climbers must be reliable, as they'll climb for 500 hours without stopping to reach the top of the SE.



**Figure 3.** A diagram of Earth's radiation belts.



## Some of the Ongoing Research

Climbers and the changing positions of the Sun and Moon will induce oscillations in the ribbon. Will the oscillations cause problems for the ribbon? If so, a means of dampening the oscillation will need to be found. Perhaps future research will show how the oscillations can be used to help climbers ascend the ribbon.

Making an SE ribbon means weaving CNTs into a ribbon. What's the longest length of CNT that can be manufactured? How does weaving them into a one-meter-wide and 22,000-mile-long (or greater) ribbon affect the ultimate strength of the ribbon? What happens to the SE ribbon as CNT fibers within it break? Will atomic oxygen in space attack the ribbon? Will climbers damage the ribbon every time they climb it? If the ribbon cannot be made from 22,000-mile-long CNTs, then a method of combining panels must be developed.

Our country had the foresight to create the National Nanotechnology Institute (NNI). With its \$990 million budget, the Institute encourages the development of nanotechnology and studies its potential health effects. While the primary focus of the NNI is not the SE, spin-offs will make their way into the design of the SE.

On a level more accessible to the amateur, the Spaceward Foundation ([www.spaceward.org](http://www.spaceward.org)) is initiating a climber competition. Amateurs and professionals alike have the opportunity to try their hand at designing a small-scale climber. The 2005 competition — for which awards of up to \$50,000 are offered — is for climbers that can climb faster than one meter per second for at least 100 feet carrying

100 pounds of payload and using a 10 kW light source for power.

You'll find information on the climber and ribbon competitions at [www.elevator2010.org/site/competition.html](http://www.elevator2010.org/site/competition.html). Perhaps those of us in robotics clubs should encourage our own, less demanding, climber competitions.

Arthur C. Clarke said we would see an SE 50 years after people stopped laughing at the idea. With the discovery of CNTs and their incredibly high strengths, people have finally stopped laughing. Perhaps we'll see the first SE in the lifetime of most *Nuts & Volts* readers.

## Final Notes

One of the many issues to resolve is how to safely traverse Earth's Van Allen Radiation Belts. I'd like to make a few comments on this topic and lay to rest one of the silliest statements made by the Moon Hoax crowd.

All moving electrical charges produce, and are affected by, magnetic fields. Earth's intrinsic magnetic field, therefore, traps moving charged particles emitted by the Sun and other sources in the depths of space. Charged particles spiral around Earth's magnetic field lines as they travel towards Earth's poles. As they approach Earth, the magnetic field lines get closer together, increasing the strength of the local field.

A charged particle will approach Earth's poles until the magnetic field becomes strong enough to bounce it back like a mirror. If a charged particle has enough energy, it can slam into Earth's atmosphere. At that point, it gives up its energy and is absorbed within the atmosphere.

With enough particles slamming into Earth's atmosphere (say, after a massive solar flare or coronal mass ejection), they will illuminate the upper atmosphere like the inside of a fluorescent light bulb — the aurora. Particles may even make it to the



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ground as cosmic rays.

Radiation primarily forms two belts around Earth and is centered equidistantly from Earth's magnetic poles (the magnetic poles are offset from Earth's rotational poles).

The inner belt consists primarily of energetic protons emitted by the Sun. These protons carry energies in the range of 10 to 100 MeV. The inner belt is located between 400 and 4,000 miles above Earth's surface. This belt was discovered by the first satellite launched by the United States, *Explorer 1*. The second belt is divided into two parts, an inner radiation belt of 1 MeV particles and an outer ring current of very low energy particles (50 KeV ions and electrons) (see Figure 3).

After a period of time, exposure to the Van Allen Belts without protective shielding is fatal. The Apollo astronauts absorbed approximately 1% of a fatal dose of radiation when they traveled over the inner belt and briefly through the outer belt. When a Moon Hoax devotee tells you that the Apollo astronauts could not have traveled through the Van Allen Radiation Belts, they're only displaying their ignorance. The radiation simply isn't that dangerous to astronauts quickly traversing the belts inside a metal spacecraft.

An SE would partially reside within the Van Allen Belts. If the SE transports people to space, then the climbers need shielding. Unfortunately, shielding usually means adding metal plates or tanks of water to the outside of the climber. The additional weight reduces the amount of cargo each climber can carry and increases the cost of each trip.

Several solutions are possible. First, climbers may be lightly shielded and make the trip through the worst parts of the belts very quickly. This doesn't prevent exposure to radiation, but it does limit it. Another possibility is that the climbers can be surrounded with powerful magnets. Some radiation will then be deflected by the climber's powerful magnetic fields. The lower the energy of the radiation, the more effective the magnetic shielding. Depending on how it's done, the radiation exposure may be as acceptable as that received during a transoceanic flight.

Alternatively, the presence of the SE may create a short circuit to the ultimate ground, Earth. Electrical current is moving electrons, and when given a short circuit to ground, they make the detour with gusto. Perhaps the SE can drain radiation out of the Van Allen Belts, thereby making radiation shielding less problematic. Of course, this will reduce the aurora displays seen on Earth. **NV**

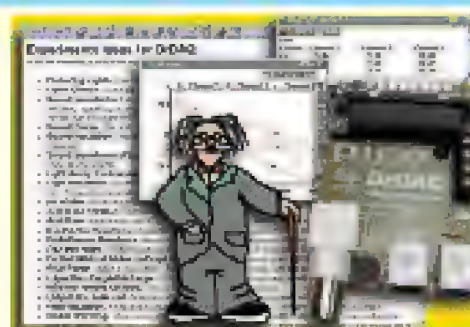
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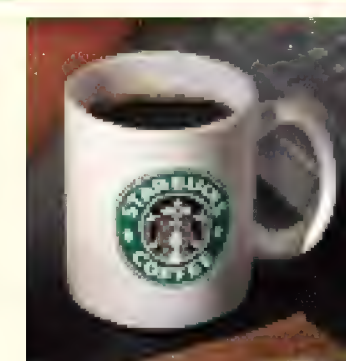
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**Don Franklin**  
via Internet

I'm a long time *Nuts & Volts* subscriber and need some help in locating a horizontal output transistor to repair a Dell monitor, model D1626HT. I need a transistor #K1120 or cross reference replacement number. So far, everything I've tried has failed.

#09056

**Anonomous**  
via Internet

This is a READER-TO-READER Column. All questions AND answers will be provided by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

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### ANSWER INFO

- Include the question number that appears directly below the question you are responding to.
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- Your name, city, and state, will be printed in the magazine, unless you notify us otherwise. If you want your email address printed also,

indicate to that effect.

- Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

### QUESTION INFO

#### To be considered

All questions should relate to one or more of the following:

- 1) Circuit Design
- 2) Electronic Theory
- 3) Problem Solving
- 4) Other Similar Topics

#### Information/Restrictions

- No questions will be accepted that offer equipment for sale or equipment wanted to buy.
- Selected questions will be printed one time on a space available basis.
- Questions may be subject to editing.

#### Helpful Hints

- Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
- Write legibly (or type). If we can't read it, we'll throw it away.
- Include your Name, Address, Phone Number, and Email. Only your name, city, and state will be published with the question, but we may need to contact you.

## ANSWERS

### [#05052 - May 2005]

*I play drums in a rock band. I would like to develop a hollow drum stick with electronics and fiber optic lights leading up the stick tip that will change color from blue to green and then from red to white based on the increasing frequency of the drum stick hitting the drum head.*

There are already novelty ballpoint pens available which contain tri-color LEDs and fiber-optics which do nearly what you are seeking. These pens change through the 6-7 different colors on a regular cycle. The only different part of your requirement is detection of drum-hits and "calculation" of the color to display.

A small eight-pin SMD (surface

SEPTEMBER 2005



mount device) microcontroller would be capable of the calculations and LED driving logic. A cheap electret condenser microphone capsule (less than \$1) and likely a single transistor "mic preamp" could provide impact information to the microcontroller.

**Richard Crowley**  
Hillsboro OR

[#05056 - May 2005]

*I would like circuit suggestions for measurement of the dark (Townsend) current in a neon bulb. I would like to use a Keithley 181 nanovoltmeter to take measurements up to six figures. I know I am using a voltmeter to measure current, but I want to get the benefits of the sensitivity and accuracy of this particular instrument. The ultimate reason for doing this is to detect radiation from biosources.*

**Gary Grinnell**  
via Internet

Measuring radiation to the degree of accuracy implied by the use of a six digit meter may not be possible with simple circuits. Though, there is a more complex circuit with some hard-to-find parts that may come close to your requirements. Should you not require high accuracy, there are some simple circuits that we can look at on the way to the complex one.

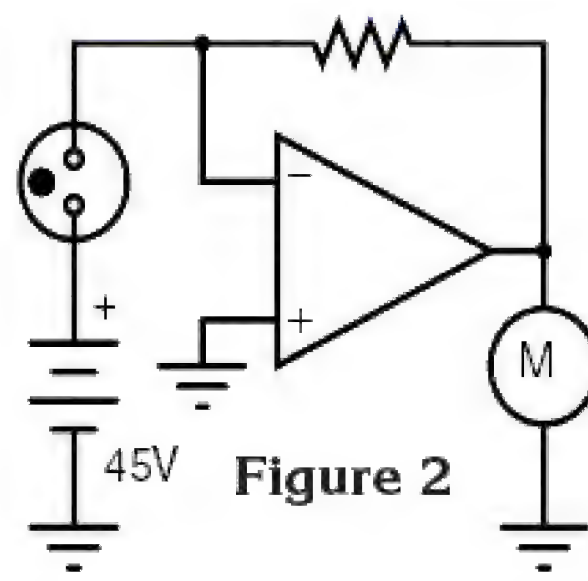
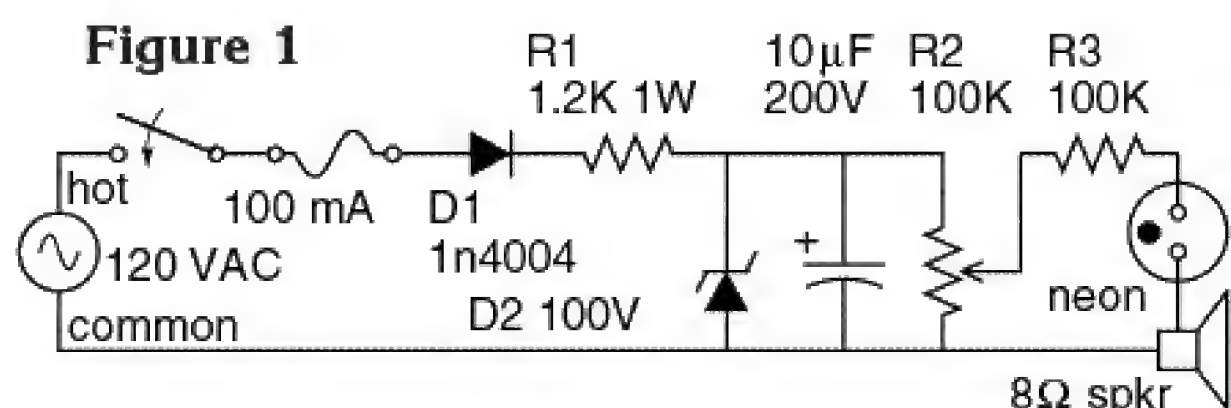
First, a circuit (Figure 1) published by Am Sonnenrain 4-71543 Wuestenrot, Germany; (e-mail: [info@peterlay.de](mailto:info@peterlay.de)) in *Electronic Design*, March 18, 2002. He has also written a book about experiments with radiation sources (in German), *Experimente mit Strahlenquellen im Haushalt* ([www.peterlay.de](http://www.peterlay.de)).

This circuit is actually a Geiger counter using a neon pilot lamp in

place of the normal Geiger-Muller tube. If radiation strikes a neutral atom of gas, a charged ion may be formed, which is accelerated toward the oppositely-charged electrode. The accelerated ion may strike other atoms forming more ions, continuing to form a multiplying cascade of ions until the neon lamp briefly conducts a current of thousands of ions. The ion arc is extinguished when the voltage across the lamp drops below the sustaining voltage. The voltage across the neon lamp is adjusted to just below the point where it would normally light. That way, it will light in response to radiation, even visible light. So, keep this circuit in the dark.

The point of the above, is that considerable amplification is required to light the lamp and click the speaker. This amplification took place in the neon lamp. This circuit does not give you the analog response which you require. It also illustrates that we need to apply a voltage across the neon lamp to have any hope of current flow due to radiation. There is a major difference in your application from the circuit in Figure 1. We do not want the neon lamp to ever go into avalanche mode and conduct. Therefore, we will never apply any voltage high enough to the neon lamp to allow that. All we want to do is measure an extremely small leakage current. The ideal circuit is shown in Figure 2.

This is an imaginary circuit because the op-amp (operational amplifier) does not exist as a discrete part. It converts current into the op-amp to a voltage at the output. Charles Wenzel ([www.techlib.com/science/ion.html](http://www.techlib.com/science/ion.html)) has built it up from discrete transistors, resistors, etc. If you need



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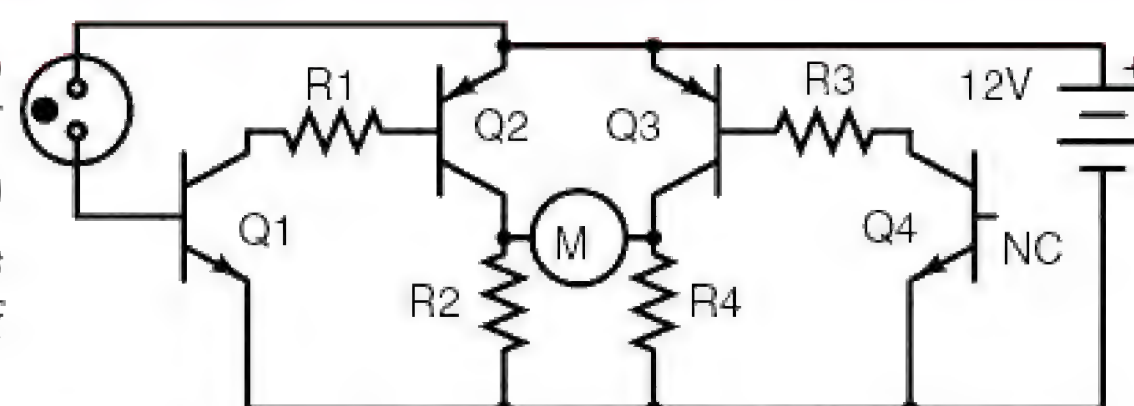
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accuracy anywhere close to that, which your six digit DVM is capable of, check out the circuit with a 100,000 megohm resistor on his website. Since you have a highly sensitive voltmeter, you may omit the OP-07 which he uses to drive a conventional meter. Remove the OP-07, 47K, 4.7M, and 0.1uF components at pin 2 of OP-07.

Connect your Keithley 181 to the left hand end (not the FET gate end) of the 100,000 megohm resistor with the common lead on the wiper of the 1K ohm potentiometer.

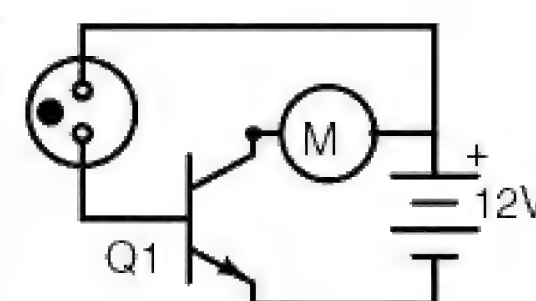
Since the 100,000 megohm resistor is a hard-to-find part, you may want to start out with some of his other circuits,



**Fig 3**

Q1, Q3 = MSPW45A Q2, Q3 = MSPA64  
R1, R3 = 10K R2, R4 = 2.2K

which will be less accurate due to being "open loop." That means that the output of the



**Fig 4**

amplifier is not fed back to the amplifier input on these simple circuits.

One of the less accurate circuits with obtainable parts is shown in Figure 3, drawn a bit condensed from Wenzel's. The transistors are Darlington pairs contained within normal three-pin packages. The virtue of this circuit is that it is a bridge circuit with the NC (No Connect) half balancing the active half with ambient temperature changes.

Half of this circuit appeared in the January issue of *Nuts & Volts*, Tech Forum. Connect your voltmeter in place of the current meter shown in that issue. If that is overly sensitive, replace the 1 mA current meter with a wire, and measure the voltage drop across the 2.2K ohm resistor.

Finally, Wenzel shows a simple circuit using a MSPW45A, and 2n2203 driving a 10 megohm voltmeter. Since you have a more sensitive 1,000 megohm Keithley 181 (I looked up the spec), I propose Figure 4 based on that circuit less the 2n2203. Once again, we use a high gain Darlington pair to amplify the current, hopefully to a level detectable by your meter.

Note that the connection from the neon lamp to the transistor base is a high impedance connection, subject to leakage. You may build all of these circuits on a perf-board, except for that one connection. It must be air-wired or supported by a clean glass or Teflon insulator, or

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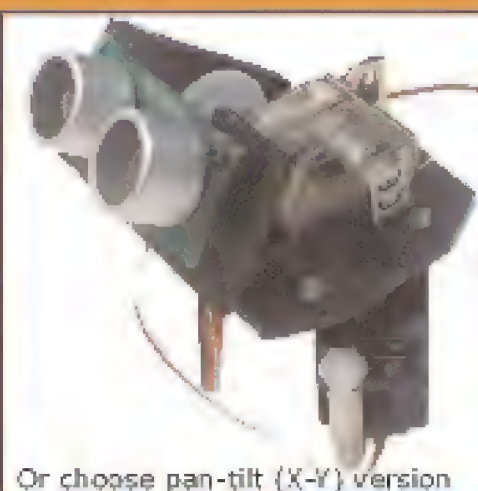
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similar insulator. These circuits may cause trouble in a high humidity environment. Enclosure in a metal box (as much as possible) will shield against stray signal pickup induced by body capacitance. Or, you can sort-of test the circuit unshielded by bringing a static charged object near the input, deflecting the meter. Actually, this proves nothing about detecting radiation, just that the circuit is sensitive, as opposed to dead.

Read Wenzel's website for tips. The 12V battery should be bypassed by a 100 uF electrolytic capacitor, not shown. Start with simple circuits first, even though you may need the "gold" circuit. If my Figure 4 does not work, move on to any of the other circuits. You may want to replace the neon lamp with Wenzel's "can sensor." If the simple circuits do not produce results, you might increase the 12V on the neon lamp to 45V (but not the

transistors) by snapping five 9V transistor radio batteries together. Finally, this is a very difficult project.

**Dennis Crunkilton  
Abilene, TX**

## [#07056 - July 2005]

*I would like to add FM radio signals to our prison cable system (94.3 MHz on Channel 60, etc.). I'll probably have to go "off the shelf" to keep it simple for staff to assemble. I'm told that RCA makes an AV accessory box for connecting AV inputs to TVs that only have a coaxial input. These boxes supposedly have an output signal tuneable to most UHF channels. I'll connect an audio cable from a radio tuner to the AV input on this box. But I believe the boxes may not have a cable input. How can I combine the AV box output with the existing cable-ready feed? Can I use a CATV splitter in reverse? Could I*

*use one of those adapters for adding an in-line UHF antenna?*

Smarthome ([www.smarthome.com](http://www.smarthome.com)) has a nifty device that converts your audio/video source into an unused TV channel (CATV 65-135 or UHF 14-69) for \$50 (which is probably less than you can make one for). The manual is available online so you can verify that it will work with your application.

See [www.smarthome.com/7715A.HTML](http://www.smarthome.com/7715A.HTML)

**John Couture  
via Internet**

## [#07051 - July 2005]

*I recently acquired about 20 four-channel 29 MHz radio-controlled cars and when used as-is, they range as far as 30 ft indoors. After slight mods, still good range, but once I install it in my car, the range becomes inches.*

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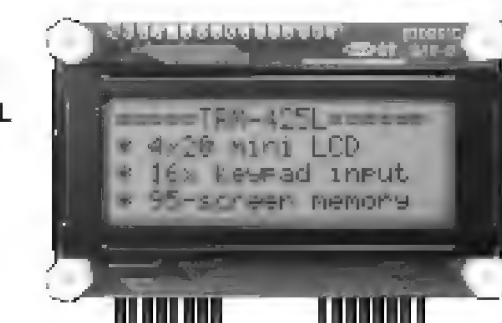
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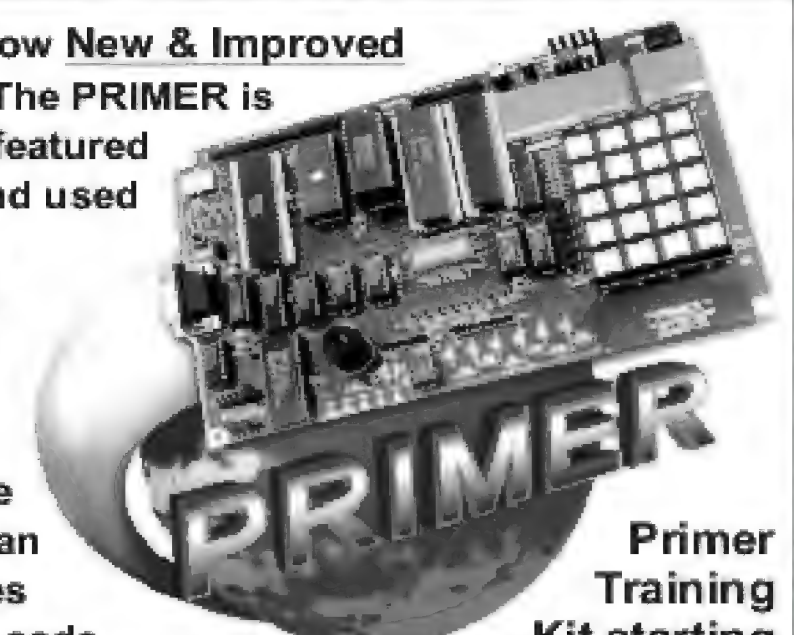
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Why is this?

**Kevin Harris**  
St. Louis, MO

Actually, 29 MHz is assigned to Amateur Radio. If your equipment was actually operating on that frequency, it was probably manufactured in China or SE Asia and would be considered illegal

to operate.

Probably it was a typing error; 49 MHz is considered a walkie-talkie and/or RC frequency of cars, boats, or planes.

Since the power output of RC transmitters assigned to that frequency are quite low, probably the car's shield has a lot to play in the attenuation of your signal.

I would suggest obtaining a quarter wave mag mount antenna (234/49) feet or about five feet long placed on top of your car. Connecting the opposite end of the coax to your RC transmitter should improve the field strength greatly.

**Theodore Turk**  
Euclid, OH

**[#08051 - August 2005]**

*I do telephone interviews (and have permission of the other party to record them). I need a phone patch circuit for a cell phone to get audio out at standard audio mixer levels that I can record via a laptop/computer sound card or cassette.*

**Clyde**  
via Internet

**#1** There are several commercially-available devices that allow audio connection in to and out of cellular phones. For example, JK Audio makes a "Cell Tap" [www.jkaudio.com/celltap.htm](http://www.jkaudio.com/celltap.htm)

There are also many DIY "phone tap" circuits and projects published on the internet. Many of these can be found in amateur-radio ("ham") contexts.

**Richard Crowley**  
Hillsboro OR

**#2** Clyde can do what he wants with a RadioShack product. Catalog #17-855 is a Wireless Phone Recording Controller for \$24.99 The unit has the 2.5 mm plug to the cell phone/wireless phone and a 1/8 plug to go into a recorder. There is a jack for a headset to monitor and talk with on top. Runs on two AAA batteries.

**Rod Hogg**  
Scott City, KS

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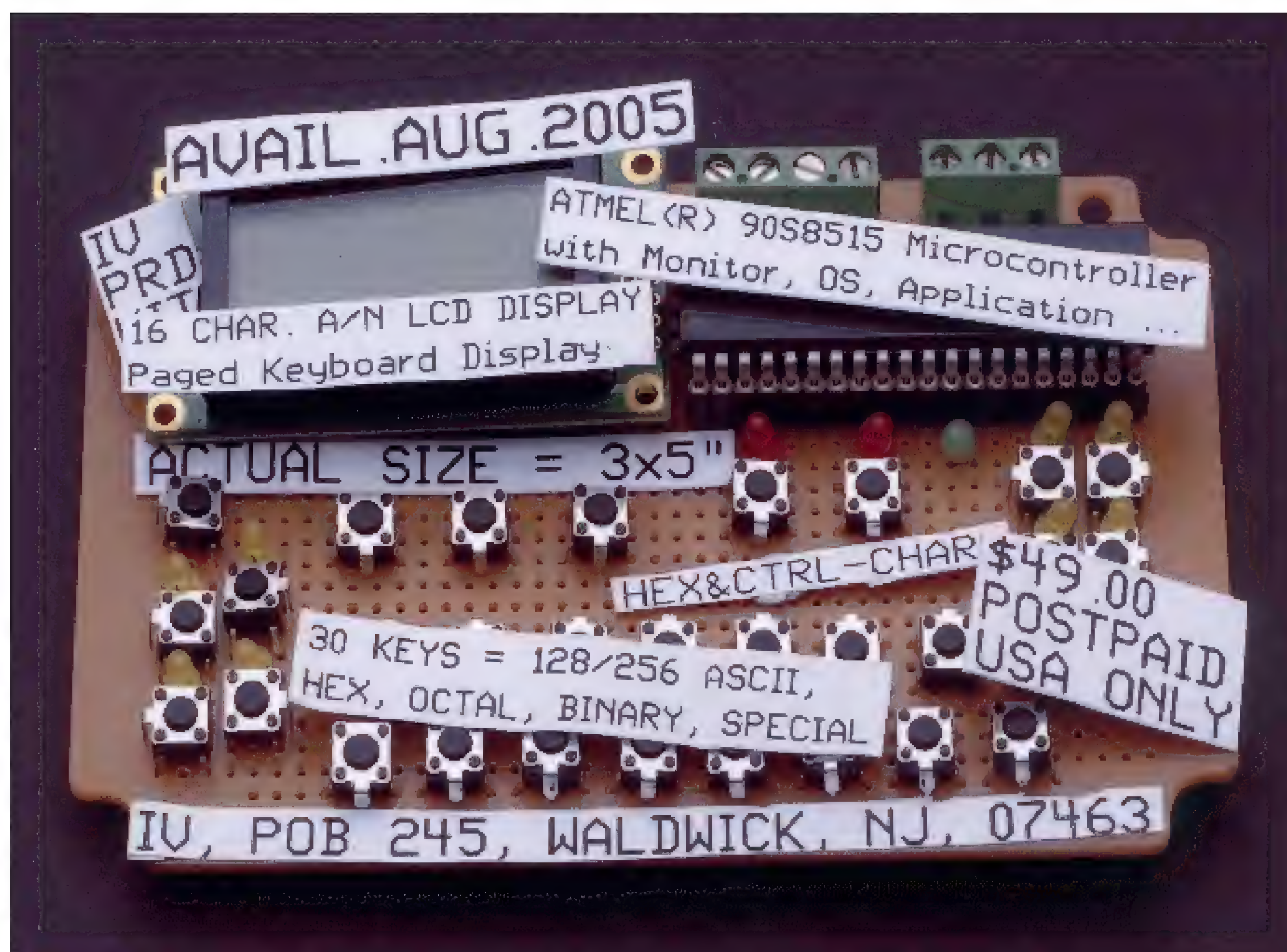
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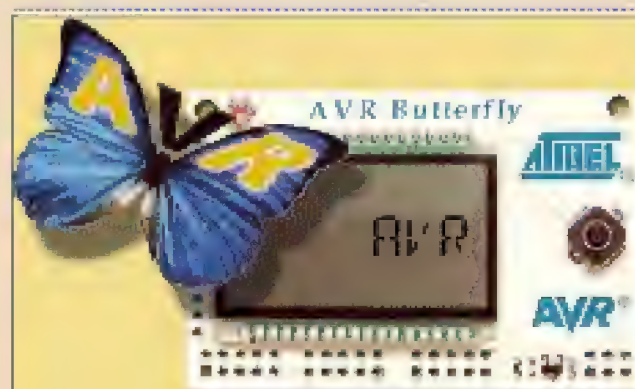
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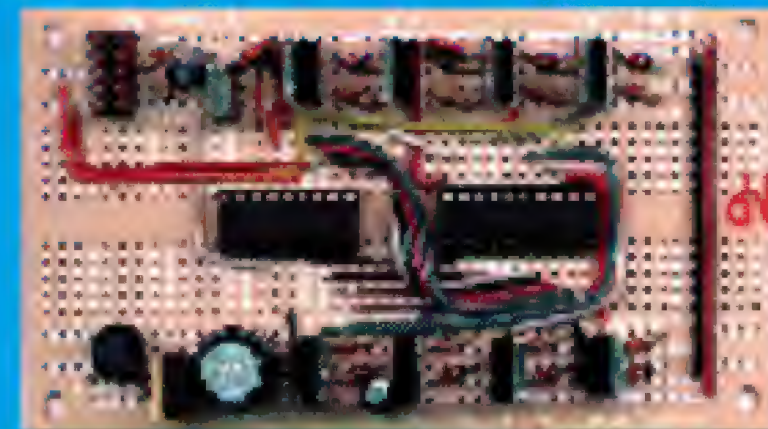
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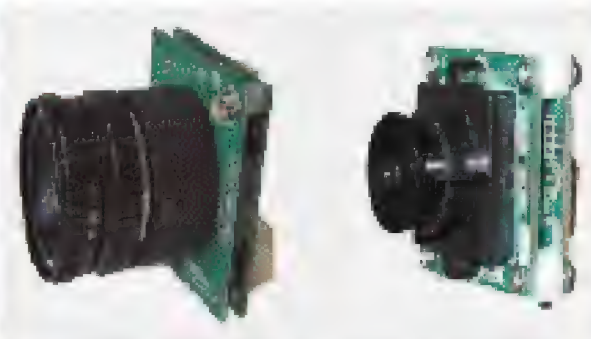
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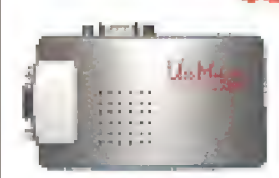
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**T**etsujin 2005 — originally scheduled for October 6-9 at RoboNexus — has been postponed. The registration deadline passed on June 13th, and there were not enough entries to hold the competition on the scheduled date.

We plan to reschedule the event sometime after the first of the year at a different venue. Individuals and teams interested in competing should drop us an email to let us know, so we can plan to go ahead and set a new date. The entry deadline will remain open for now. Don't send money or the entry form yet, just email to let us know you are interested in competing and we'll keep you posted on what to do next and when to do it.

Hey, look on the bright side, not only do you *STILL* have time to enter, you have even *MORE* time to design and build your exosuit! So, there's no excuse now *NOT* to compete! This is a hard competition and certainly one worth participating in. If it were easy, everyone would be doing it. This is your chance to stand apart from the crowd and flex your engineering and bot-building

muscles. So, hook up with your friends, fellow engineers, classmates, geeksquad, gearheads, whoever, and form a team. No need to go it alone!

If you haven't already done so, check out the new rule set and event changes and start scribbling out your preliminary design. There's no time to lose! **Send an email to [tetsujin@servomagazine.com](mailto:tetsujin@servomagazine.com)** with your name and email address and we'll make sure you get all the latest info and news.



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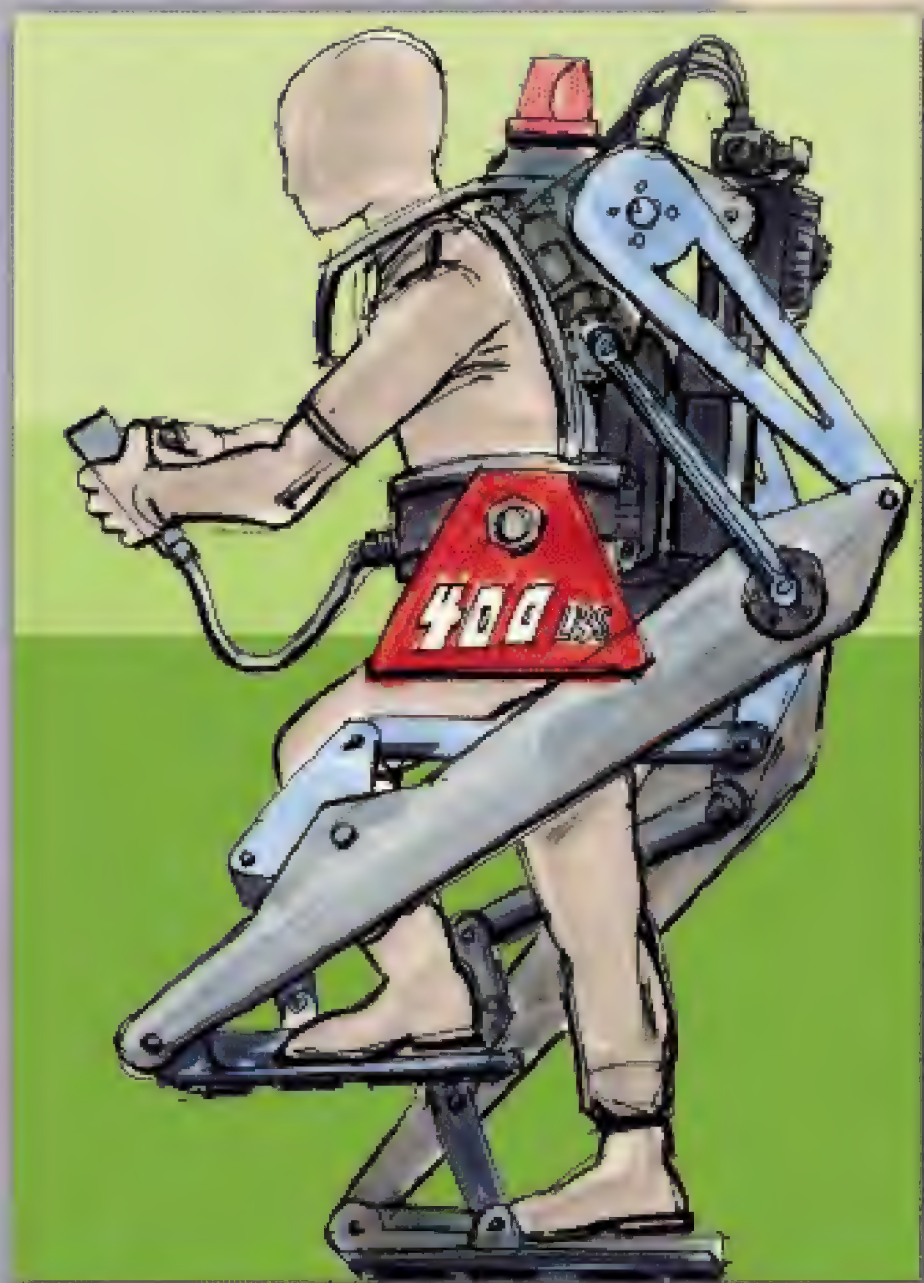
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## **CHALLENGE 2:**

**Dexterity.** Stack nine concrete cylinders weighing about 70 pounds each in a 4-3-2 vertical arrangement, but don't knock them over as the pyramid grows! The winner is the competitor who arranges the cylinders in the shortest time.

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The current rule set is available online at  
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\*Specifics of the competition are in a tentative state and may be subject to change.



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**LED Panel Meters: 3-1/2 Digits**

	9V Independent Ground (PM-129A).....	\$12.49
	5V Common Ground (PM-129B).....	\$12.95
	9V Independent Ground (PM-1029A).....	\$14.95
	5V Common Ground (PM-1029B).....	\$15.95
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**Details & Specs at Web Site**

> Panel Meters > Digital Panel Meters



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- Replaceable iron/easy disconnect
- Extra tips etc. shown at web site

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**Also Available w/Digital Display & MicroProcessor Controller**

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Adaptor Fits CSI Stations 1 & 2, and also CSI906

**\$29.00**

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**Since 1971**

**Bullet Style B/W Camera**

- Weather Proof
- Signal System: EIA
- Image Sensor: 1/3" LG CCD
- Effective Pixels: 510 x 492
- Horizontal Resolution: 420TV lines
- Min. Illumination: 1Lux/F1.2



Item# **VC-305**

1-4: \$49.00 5+: \$46.00

Details at Web Site

> Miniature Cameras (Board, Bullet, Mini's, B/W, Color) & Security

**High Capacity Nickel Metal Hydride Rechargeable Batteries**

Item#		1+	10+	100+
AA2500MAH	"AA" cell 2500mAH	\$1.45	1.25	1.09
AAA850MAH	"AAA" cell 850mAH	\$0.99	0.65	0.51
C3500MAH	"C" cell 3500mAH	\$2.99	2.30	2.09
D11000MAH	"D" cell 11000mAH	\$6.95	5.55	4.39
9V220MAH	"9V" cell 220mAH	\$3.69	3.29	2.99

Details at Web Site

> Batteries & Accessories > NiMH Batteries

**13.8V DC Regulated Linear Power Supplies**

Rugged power supplies that provide 13.8 Volts and substantial amounts of current! Suitable for various applications including Automotive, Marine and Radio Equipment, along with High-Amp Stepper Motors and CNC (Computer Numeric Control) Machines. Choose from three models; CSI1862 with 6 Amps, CSI-1865 with a robust 20 Amps or CSI-1869 with a beefy 40 Amps at your disposal.

Item#	Current	Price
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CSI-1865:	(20A)	\$69.00
CSI-1869:	(40A)	\$119.00

**NEW!**



Details at Web Site > Test Equipment > Power Supplies > DC Power Supplies

**Triple Output Bench Power Supply**

with Large LCD Displays



Output: 0-30VDC x 2 @ 3 AMPS  
& 1ea. fixed output @ 5VDC@3A  
Source Effect:  $5 \times 10^{-4} = 2\text{mV}$   
Load Effect:  $5 \times 10^{-4} = 2\text{mV}$   
Ripple Coefficient:  $< 250\text{uV}$   
Stepped Current: 30mA +/- 1mA  
Input Voltage: 110VAC

**CSI3003X3/\$179.00**  
(qty 5+/\$169.00)

Details at Web Site

> Test Equipment > Power Supplies

**Protek 100MHz Realtime Scope**

2 Ch Dual Trace  
6" Internal Grid  
ALTMAG  
ALTTRIG  
TV Sync  
5 Vertical Modes



Item# **6510**

Brand New  
Not Refurbished!  
Includes 2 scope probes

**A \$975.00 Value!**  
**100MHz only \$499.00**

While Supplies Last!

Details at Web Site > Test Equipment > Oscilloscopes/Outstanding Prices

**Focused Infrared Soldering System**

It can be used widely for reworking BGAs, micro-BGAs, QFPs, PLCCs, SOICs, small SMDs, components in mobile phones, computers, and other circuit board components without overheating. Generates heat through concentration of infrared heat waves instead of conventional hot air.

**\$1590.00**



Item# **CSI-IR1**

**NEW!**

Details at Web Site

> Soldering Equipment & Supplies > Infrared Soldering

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High stability digital read-out bench power supplies featuring constant voltage and current outputs. Short-circuit and current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance and long life.

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- Load Effect:  $5 \times 10^{-4} = 2\text{mV}$
- Ripple Coefficient:  $< 250\text{uV}$

\*Both Models have a 1A/5VDC Fixed Output on the rear panel\*  
**CSI3003X-5: 0-30v/0-3amp/1-4..\$97.00/5+..\$93.00**  
**CSI5003X-5: 0-50v/0-3amp/1-4..\$107.00/5+..\$103.00**

Details at Web Site > Test Equipment > Power Supplies

**As Low As \$93.00!**



**HOT ITEM!**



**Premier Repairing System w/Power Supply**

Microprocessor controlled design that provides stability and precision of temperature and airflow settings during the rework process. A full digital display of temperature and power source make everything clear to the user while the unit provides vast flexibility at the rework station with the built-in power supply that provides 15V and 2A of power. Hot air soldering and adjustment of temperature are controlled by a micro chip and sensor thus giving tremendous accuracy and reliability.

Item# **CS1768****Only \$289.00!**

- Iron Output Voltage: 24V / 35W
- Temperature Range: 100-480°C / 212-896°F
- DC Power Supply: 15V / 2A

**NEW!**

Details at Web Site &gt; Soldering Equipment &amp; Supplies

**2.9GHz RF Field Strength Analyzer**

The **3290** is a high quality hand-held RF Field Strength Analyzer with wide band reception ranging from 100kHz to 2900MHz. The 3290 is a compact & lightweight portable analyzer & is a must for RF Technicians. Ideal for testing, installing & maintenance of Mobile Telephone Comm systems, Cellular Phones, Cordless phones, paging systems, cable & Satellite TV as well as antenna installations. May also be used to locate hidden cameras using RF transmissions.

Item# **3290**

Details at Web Site &gt; Test Equipment &gt; RF Test Equipment

**Fantastic Low Price: \$1899.00!**

- WFM/NFM/AM/SSB modulated signals may be measured.
- Signal Levels up to 160Channels can be displayed simultaneously on the LCD
- PLL tuning system for precise frequency measurement and tuning
- Built-in Frequency Counter
- LED Backlight LCD (192x192 dots)
- All functions are menu selected.
- RS232C with software for PC & printer interface
- Built-in speaker

**(Includes Antenna)****B&W Pinhole Bullet Camera w/ 1/3" CCD**

- Weather Resistant Housing
- Signal System: EIA
- Image Sensor: 1/3" CCD Bullet Hole
- Effective Pixels: 510 x 492
- Horizontal Resolution: 380TV lines
- Min. Illumination: 1Lux/F1.2

Item# **VC-305CP**1-4: **\$49.00**5+: **\$46.00**

Details at Web Site

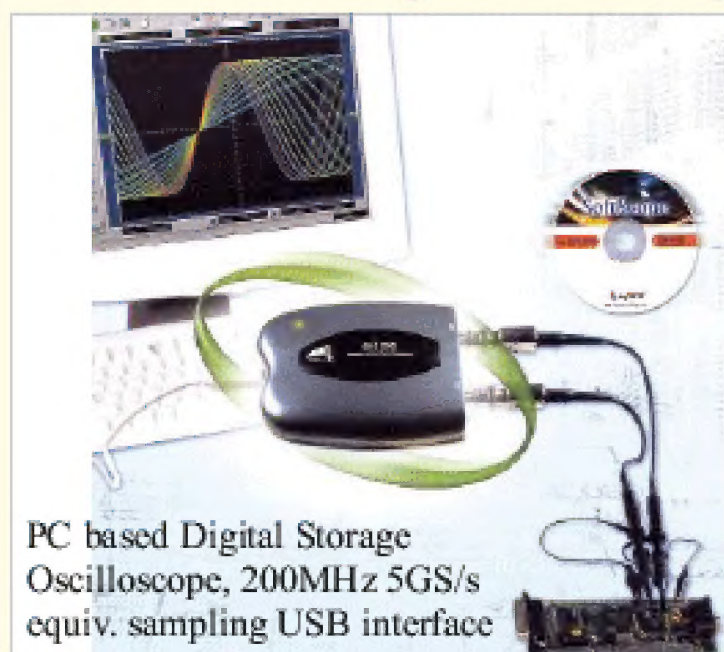
&gt; Miniature Cameras (Board, Bullet, Mini's, B/W, Color)

**4 Channel Digital Video Recorder**

- Signal System: NTSC
- Operation System: Embedded RTOS
- Video Input: BNC x 4
- Video Output: BNC x 1 / VCR OUT
- Resolution: NTSC 720x480/ NTSC 640x240
- HD Capacity: Max. Capacity up to 250GB
- Backup: VCR
- Alarm In/Out: 4 in NO/NC, 1 Out No

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PC based Digital Storage Oscilloscope, 200MHz 5GS/s equiv. sampling USB interface

Convert any PC with USB interface to a high performance Digital Storage Oscilloscope. This is a sophisticated PC based scope adaptor providing performance compatible to mid/high level stand alone products costing much more! Comes with two probes.

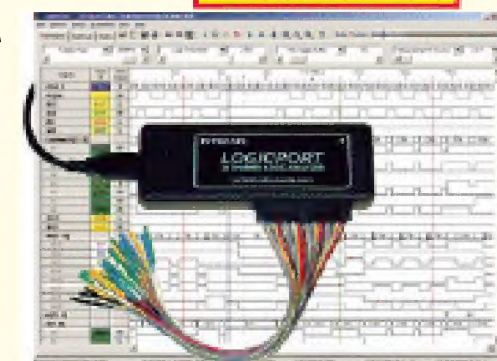
Details & Software  
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&gt; Test Equipment &gt; Oscilloscopes/Outstanding Prices

Item# **200DSO** Only **\$899.00****LogicPort Logic Analyzer**

The LogicPort provides 34 sampled channels including two state-mode clock inputs. It connects to your PC's USB port for ultimate convenience and performance.

- 34 Channels
- 500MHz Timing mode sample rate
- 200MHz State mode sample rate
- Real-time Sample Compression
- Multi-level trigger
- +6V to -6V Adjustable Threshold

Item# **LOGICPORT**

Details at Web Site &gt; Test Equipment &gt; Logic Analyzers

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Item#	Description
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<b>3A-161WU06</b>	6 Volts / 2.5 Amps
<b>3A-161WU09</b>	9 Volts / 1.70 Amps
<b>3A-161WU12</b>	12 Volts / 1.25 Amps
<b>3A-161WU18</b>	18 Volts / 0.84 Amps
<b>3A-161WU24</b>	24 Volts / 0.63 Amps

Each	10+	25+	100+
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Details at Web Site &gt; Test Equipment &gt; Power Supplies

**NEW!****SONY Super HAD CCD Color Weatherproof IR Cameras**

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 480TV lines
- Min. Illumination: 0Lux

Item# **VC-827D** 1-4: **\$149.00** 5+: **\$139.00****480 TV Lines Resolution****SONY Super HAD CCD B/W Weatherproof IR Camera**

- Day & Night Auto Switch
- Signal System: EIA
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# **VC-317D** 1-4: **\$69.00** 5+: **\$65.00****SONY Super HAD CCD™ equipped camera's feature dramatically improved light sensitivity****SONY Super HAD CCD Color Camera**

- Weather Proof
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 1Lux/F1.2

Item# **VC-805** 1-4: **\$69.00** 5+: **\$65.00**

Details at Web Site

&gt; Miniature Cameras (Board, Bullet, Mini's, B/W, Color)

**SONY Super HAD CCD Color Weatherproof IR Camera**

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# **VC-819D**  
1-4: **\$89.00** 5+: **\$79.00****SONY Super HAD CCD Mini B/W Board Camera**

- Signal System: EIA
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 420TV Lines
- Min. Illumination: .05Lux/F1.2

Item# **VC-103** 1-4: **\$33.00** 5+: **\$29.00**

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**Melexis Hall-Effect Sensor (#605-00005; \$4.25) & Magnet (#605-00006; \$0.79).** Place a magnet near the sensor to measure detection or RPM on a shaft or turning object.



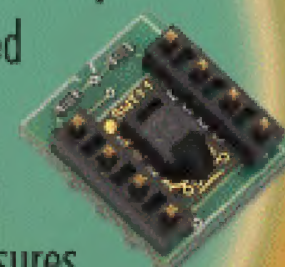
**QT113-D Touch Sensor (#604-00038; \$3.95).**

QTouchT ICs create sense fields through dielectric surfaces such as plastic or glass up to 100mm (4") thick, and can even turn small objects into sensors.



**Sensirion Temperature/Humidity Sensor (#28018; \$29.00).**

A pre-calibrated synchronous serial interface in a tiny package measures humidity and temperature.



**PING)))™ Ultrasonic Sensor (#28015; \$24.95).** Parallax's new PING))) ultrasonic sensor provides distance measurement up to three (3) meters.



**Piezo Film Vibra Tab Mass (#605-00004; \$1.49).** Whether used as a vibration sensor, a flexible switch, or a frequency response device, piezo film is an interesting sensor to interface with BASIC Stamp® modules.

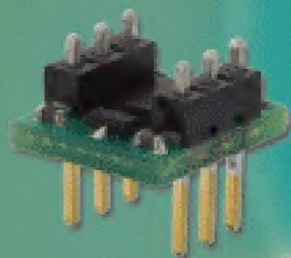


**TSL230 Light to Frequency Converter (#27924; \$4.75).**

The TSL230 precisely measures light using an array of photodiodes, with an output of digital square waves.



**Hitachi HM55B Compass Module (#29123; \$29.95).** Sensitive to minute variations in magnetic field strength, this sensor provides 64+ direction resolution.

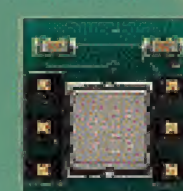


**TCS230 Color Sensor (#30054; \$79.00).** This module can detect and measure a nearly limitless range of visible colors.



**Memsic 2125 Dual-axis Accelerometer (#28017; \$29.00).**

Thermal accelerometer capable of measuring vibration, incline and gravity with a range of  $\pm 2$  g.



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